VOLUME I OF VIII
MOTTOLO SITE
REMEDIAL INVESTIGATION REPORT
SECTIONS 1 THROUGH 7

Submitted to:

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# MOTTOLO SITE
# REMEDIAL INVESTIGATION REPORT

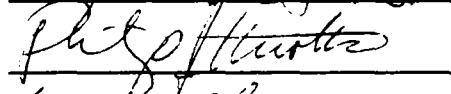## MOTTOLO SITE RI/FS
## RAYMOND, NEW HAMPSHIRE

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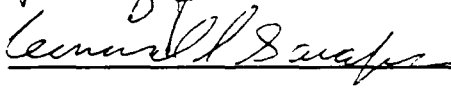QA/QC OFFICER: _____ DATE: 10/03/90

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## EXECUTIVE SUMMARY

The Mottolo Superfund site is located in Raymond, New Hampshire at the location of a former piggery operation where from 1975 through 1979 the property owner disposed of approximately 1,600 55-gallon drums and 5-gallon pails containing liquid and solid waste materials into a depression adjacent to the main piggery building. Preliminary investigations conducted by the New Hampshire Water Supply and Pollution Control Commission (WSPCC) indicated that the disposal area was contaminating soils, surface water, and ground water with volatile organic compounds (VOCs) such as, 1,1,1-trichloroethane, trichloroethene, toluene, ethylbenzene, xylenes, and tetrahydrofuran. During 1980 through 1981, the United States Environmental Protection Agency (EPA) removed the drums, pails and some contaminated soil and transported the material off-site to disposal facilities. In the ensuing years, investigations conducted by the WSPCC indicated the presence of an area of contaminated ground water extending from the former drum disposal area east to a small brook on the Mottolo property known as Brook A. Due to the close proximity of a residential development located north of the Mottolo site, the WSPCC initiated a monitoring program which included the sampling of residential wells and analyses of the ground water samples for VOCs. Trace concentrations of VOCs were reported in residential well samples during the monitoring program with data not indicating a link to the Mottolo site.

In 1987, the Mottolo site was added to the National Priorities List and later that year EPA and one of the potentially responsible parties (PRPs), K. J. Quinn & Company, Inc. (Quinn), began negotiations to conduct a remedial investigation/feasibility study (RI/FS). In May 1988, a Consent Agreement between EPA and Quinn was completed and RI field activities commenced in October. The purpose of the RI was to generate data to adequately characterize the site for the purpose of evaluating and developing an effective remedial alternative.

## SITE BACKGROUND

The Mottolo Superfund site is located on Blueberry Hill Road in southeastern Raymond, which is located in southeastern New Hampshire. The approximately 50-acre property is primarily undeveloped land divided in half by Brook A which originates in a wetland area beyond the southern property boundary and flows north through the property and the residential area, eventually discharging to the Exeter River. Approximately two acres of the property remain cleared from the former piggery operated on site, disposal activities, and EPA waste removal operations. The cleared area is divided by a drainage swale which flows from west to east, discharging to Brook A. The Mottolo property is bounded by a rural residential neighborhood to the north, to the south and east by properties planned for residential development, and to the west by several residences and heavily wooded, undeveloped land.

The topography in the Raymond area is typical of glaciated regions of southern New Hampshire which are characterized by low lying hills with relatively gradual slopes which are covered with a thin veneer of glacial till through which bedrock outcrops at many locations.

Based upon information obtained during previous investigations including ground water, surface water, and soil quality, several investigations were conducted during the RI to further characterize the study area and describe the nature, sources, and extent of contamination. These investigations included:

o       Development of detailed surface topographic maps for the study area.

o       A review of historical aerial photography dating from 1966 to 1988.

o       Inspection and measurement of structural features exhibited at bedrock outcrop locations throughout the study area.

o   Two phases of geophysical investigations on site, and one phase off site in the residential area north of the Mottolo site. These studies included electromagnetic conductivity surveys utilizing Geonics EM-31 and EM-34 methods, seismic refraction profiling, and a proton precession magnetometer survey.

o   A soil gas survey utilizing a Photovac 10S50 gas chromatograph.

o   A three-phased soil boring program in and around the former drum disposal area and a drum staging area.

o   A ground water investigation which included the on-site installation of eleven overburden wells and fifteen shallow bedrock wells, and the off-site installation of two overburden wells, and six 225-foot-deep bedrock wells at locations in the residential area.

o   The collection and screening of soil samples for VOCs and the collection of rock core during the drilling programs.

o   Aquifer testing at multiple wells using slug test methods.

o   Brook A and drainage swale stream gauging and a base flow analysis.

o   A wetlands survey.

o   Three rounds of ground water and surface water sampling conducted during 1989 in April, September and December. The first round included sediment sampling in Brook A and the drainage swale. Samples were analyzed for full Hazardous Substance List (HSL) compounds and numerous general chemistry parameters. Samples collected during the subsequent rounds were analyzed for VOCs and several selected parameters.

o    Residential well water collection and analyses by the New Hampshire Department of Environmental Services (NHDES) coincident with the three rounds of monitoring well sampling.

o    Air quality monitoring.

## PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The Mottolo site is located on the western flank of the Brook A drainage basin; therefore, rainfall runoff and surface water from the Mottolo site generally flow east toward Brook A which ultimately flows north discharging to the Exeter River. The study area is overlain with generally less than 20 feet of glacial and fluvial deposits. The overburden appears to thicken approaching Brook A and was identified to be up to 45 feet deep in the residential area to the north. Within the upland site areas, overburden deposits consist primarily of fine to coarse sand with pockets of gravel and boulders identified as a glacial till. Overburden deposits east of the former drum disposal area in the area of Brook A consist primarily of an alluvial or glacio-fluvial fine sand.

Bedrock in the study area consists of metamorphic and igneous formations including biotite granofels and biotite schist which have been intruded by sills and dikes of granitic material. Bedrock surface topography generally follows ground surface topography. Based upon field observation of bedrock outcrops and rock cores, bedrock in the study area appears to be only slightly weathered and moderately fractured. Data collected during the RI indicate two dominate joint orientations in the bedrock at approximately 45 degrees northeast and 120 degrees southeast. Ground water yields from the bedrock are generally low, at less than 5 gallons per minute, although greater yields are likely from fracture zones such as were encountered in one of the residential area monitoring wells where greater than 50 gallons per minute yield was estimated. Based upon potentiometric data collected during the RI, the conceptual hydrogeologic model developed for the study area is one in which ground water flow in the site area appears to be primarily

controlled by local topography, the slope of the bedrock surface, and Brook A, which has been identified as the local ground water discharge feature. Detailed site area data indicate ground water in the overburden beneath the former disposal area flows both east along the approximate path of the drainage swale as well as downward into the upper bedrock and then east to Brook A. A lesser component of ground water flow in the bedrock to the northeast and to Brook A has also been identified. Vertical hydraulic gradients in the upland area including the former disposal area are downward from the overburden to the bedrock; hydraulic gradients in the Brook A valley lowland area are upward from the bedrock to the overburden and Brook A. A local ground water divide was identified south of the former disposal area and the area of the piggery building and the large concrete pad. Data suggest that ground water south of this divide is likely to flow south and then east before discharging to the head water area of Brook A, southeast of the site. Average ground water travel times from the former disposal area to Brook A through the overburden range from 1 to 4 years, whereas travel times for ground water flow from the bedrock beneath the former disposal area to the overburden bedrock interface beneath Brook A are approximately 1 to 14 days.

## NATURE AND EXTENT OF CONTAMINATION

Based upon a review of data collected during the RI, two source areas of contamination were identified. An area of contaminated soils approximately 150 feet by 75 feet in the former drum disposal area is the most significant source area contributing to ground water contamination identified during the RI as a result of previous waste disposal activities. A second potential source area was identified west of the piggery building in the vicinity of a large concrete pad near the southern boundary where overburden and bedrock ground water contamination was identified. The specific source of contamination in the southern boundary area was not located although it is hypothesized that the contaminants are the result of either previous site activities during waste disposal operations or EPA drum staging activities conducted in this area. Initially, soil, ground water,

surface water, and sediment samples were analyzed for HSL volatile organic, semi-volatile organic, PCB/pesticide and inorganic compounds, as well as several general chemistry parameters. Based upon a review of these data, volatile organic compounds were identified as the contaminants present at the most significant concentrations in soils, sediments, ground water and surface water.

The greatest concentrations of VOCs detected in soils were found at or above the water table in the former drum disposal area and included aromatic hydrocarbons (toluene, xylenes, and ethylbenzene), chlorinated VOCs (trichloroethene, methylene chloride, and tetrachloroethene), and the ketone acetone. Of the VOCs, toluene, ethylbenzene, xylenes, and methylene chloride were generally reported at the greatest concentrations (greater than 1 parts per million (ppm)) and were identified in the greatest number of samples analyzed by laboratory or Photovac GC techniques. Total VOC concentrations reported in soil samples collected in the former disposal area, and analyzed by CLP methods, ranged from 0.002 to 465.2 ppm. The majority of the soil samples analyzed were reported to contain less than 0.5 ppm total VOCs.

VOCs were also the most common compound group reported present in ground water samples and included the aromatic compounds toluene, ethylbenzene, and xylenes; the chlorinated hydrocarbons vinyl chloride, 1,2-dichloroethene (total), trichloroethene, and 1,1,1-trichloroethane; and tetrahydrofuran. Total VOC concentrations reported during the RI in ground water samples collected from monitoring wells immediately downgradient of the former disposal area ranged from 0.627 to 25.3 ppm in the overburden and 0.325 to 3.37 ppm in bedrock. Approximately 150 feet downgradient and adjacent to Brook A, concentration ranges in ground water are reduced to 0.251 to 1.238 ppm in the overburden and 0.161 to 0.652 ppm in bedrock. Total VOC concentrations reported in ground water samples collected in the southern boundary area ranged from not detected to 0.13 ppm in the overburden and 0.227 to 1.132 ppm in bedrock. Arsenic was the only other compound identified as a constituent of concern present in site ground water at elevated concentrations.

Overburden and bedrock ground water quality data indicate that the contaminants migrate predominantly east from the former disposal area approximately 300 feet and discharge in the area of Brook A. Lesser components of contaminant migration were identified from the former drum disposal area to an area approximately 600 feet northeast along Brook A and north from the drainage swale along the lowland area west of Brook A. Consequently, the northern extent of detectable ground water contamination is estimated at greater then 500 feet south of the northern Mottolo property boundary.

Ground water quality data collected during the RI revealed the presence of trichloroethene, 1,2-dichloroethene (total), and tetrahydrofuran in samples from wells located near the southern property boundary at concentrations generally less than 1 ppm. Ground water is believed to flow south/southeast from this area in both the overburden and bedrock and ultimately discharge in the area of Brook A. Analytical results of surface water samples collected during the RI indicate that Brook A surface water downstream of its confluence with the drainage swale is impacted by low concentrations of VOCs, generally less than 0.015 ppm. Sediment samples collected at the same stations as surface water samples during the first sampling round indicated contaminant distribution trends similar to the surface water samples. Air screening conducted throughout the course of outside RI activities did not indicate the presence of detectable levels of VOCs in breathing zone ambient air.

Analytical data provided by NHDES for samples collected from residential wells during the three RI sampling rounds in 1989 indicated that VOCs were reported present at trace levels in only three samples, in three different wells, on different sampling dates. The compounds detected at trace levels appeared to be related to local sources other than the Mottolo site. Potential sources of these VOCs may include plastic pipe cement used during residential well pump system installation, paint thinner, cleaning solvents, petroleum hydrocarbon products, and residential construction materials.

## CONTAMINANT FATE AND TRANSPORT

The source most responsible for contaminants detected in ground water at the Mottolo site is the contaminated soils remaining in the former disposal area. Ground water quality data collected during the monitoring program indicate that the greatest release of contaminants to ground water likely occurs in the spring when water levels in the overburden rise as much as 5 feet into more highly contaminated soils. Pathways for contaminant migration from the source area include lateral ground water flow through the overburden to Brook A and an easterly/northeasterly ground water flow path through the bedrock to Brook A influenced by the fracture and joint orientations. Contaminants identified in the southern boundary area are likely to flow from the shallow overburden downward into bedrock ground water and then migrate south and southeast where they are expected to discharge with ground water at the Brook A headwater area.

In general, the extent of ground water contamination appears to be governed by advective ground water transport through the overburden and fractures in bedrock. As such, the southern and eastern boundaries of the contaminated ground water plume originating from the former disposal area appeared to be well defined by ground water flow pathways and boundaries. Dispersion is also responsible for spreading of the VOC plume to the north in both the overburden and bedrock on the west side of Brook A. Data indicate that VOCs in ground water ultimately discharge to the Brook A area where they volatilize and dilute to non-detectable levels over a distance of a few hundred feet. Detectable levels of arsenic have not been identified in water samples collected from Brook A suggesting that the arsenic may be removed by sorption on soil and sediment particles prior to reaching Brook A and that the size of the source is not large.

Since the drums were removed in 1980 and are no longer a source, it is likely that desorptive processes are currently occurring across the site in residually contaminated soils. A comparison of historic ground water quality analytical data collected between 1980 and 1989 indicated that contaminant concentrations have

decreased in surface water and ground water throughout this period. VOC concentration reduction factors between 2 and 20 indicate that impacts of the Mottolo site on ground water quality have declined with time and are likely to continue to do so in the future.

## BASELINE RISK ASSESSMENT

A risk assessment was performed to assess baseline conditions at the site and to evaluate potential risks to human health and the environment in the absence of remediation. The evaluation was divided into three major sections: the hazard identification and dose-response assessment, the exposure assessment, and the risk characterization.

Within the hazard identification and dose-response assessment, indicator compounds were selected for each environmental medium based on their toxicity, carcinogenicity, frequency of occurrence, relation to applicable standards or naturally occurring background levels, mobility, or persistence. Selected indicator compounds for the following media included:

o       ground water - arsenic, 1,1-dichloroethane, 1,2-dichloroethene (total), ethylbenzene, tetrahydrofuran, 1,1,1-trichloroethane, toluene, trichloroethene, and vinyl chloride

o       surface water - 1,1-dichloroethane and 1,2-dichloroethene (total)

o       sediment - 1,1-dichloroethane and 1,1,1-trichloroethane

o       soil - ethylbenzene, toluene, and xylene

Potential exposure pathways were selected for evaluation and exposure doses estimated whereby on-site and off-site areas were considered under current and future conditions. Selected on-site exposure pathways included ingestion, dermal absorption, and inhalation of vapors from ground water, and ingestion and dermal contact scenarios for on-site surface water, sediment, and soil. Off-site exposure

pathways were not evaluated for lack of potential exposure points or potential receptors.

Calculated risk estimates using current and future scenarios for ingestion and dermal contact with on-site surface water, sediment, and soil were found to be within target levels of risk. However, future risks associated with the ingestion of ground water derived from domestic wells installed within the former drum disposal area were calculated to be outside the target EPA range of 1E-04 to 1E-06 for incremental lifetime cancer risk. Carcinogenic risk estimates bordered on target levels for ground water derived from bedrock along an area near the southern property boundary. Noncarcinogenic risks for ingestion of ground water derived from either the former drum disposal area or along the southern property boundary were slightly above target levels. Risk estimates for dermal contact with ground water were calculated to be at target levels. Based upon a qualitative evaluation of potential risks associated with the inhalation of vapors from ground water during household use, it is expected that the risks associated with ground water from the former drum disposal area may be greater than risks associated with ground water from the southern boundary area.

Based upon the data gathered during the RI, it appears that ground water contamination related to disposal activities at the Mottolo site is limited to an area within the Mottolo property and a smaller area south of the property, and that contaminant migration is controlled by local ground water discharge in the area of Brook A. Data collected in the residential area to the north and downgradient of the Mottolo site, between 1980 and 1990, do not indicate that this area has been impacted by activities related to the Mottolo site.

**BALSAM**
ENVIRONMENTAL CONSULTANTS, INC.
Engineering, Environmental Science & Industrial Hygiene

# 1.0 INTRODUCTION

The Mottolo Superfund site is located in Raymond, New Hampshire at the location of a former piggery operation. From 1975 through 1979, the property owner disposed of approximately 1,600 55-gallon drums and 5-gallon pails containing wastes into a depression adjacent to the main piggery building. In 1979 the site was reported to state officials and preliminary investigations conducted by the New Hampshire Water Supply and Pollution Control Commission (WSPCC) indicated that the disposal area was contaminating soils, surface water and ground water with volatile organic compounds (VOCs) such as 1,2-dichloroethene, 1,1,1-trichloroethane, trichloroethene, toluene, ethylbenzene, xylenes, and tetrahydrofuran. During 1980 through 1981, the U.S. Environmental Protection Agency (EPA) removed the drums, pails, and some contaminated soil and transported the material to off-site disposal facilities. In the ensuing years, several investigations were conducted by the WSPCC to determine the degree and extent of contaminated soil, surface water and ground water at the Mottolo site. These studies indicated the presence of a relatively limited area of contaminated ground water extending from the former drum disposal area east to a small brook on the Mottolo property. Due to the close proximity of a residential development which was located north of the Mottolo site, the state investigations included the sampling of residential wells and analyses of the ground water samples for VOCs.

In 1987, the Mottolo site was added to the National Priorities List (NPL). In late 1987, one of the potentially responsible parties (PRPs), K.J. Quinn & Company, Inc. (Quinn), began negotiations with the EPA to conduct a remedial investigation/feasibility study (RI/FS). The RI/FS was developed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment and Reauthorization Act (SARA), in accordance with procedures governing the participation of PRPs. The process of developing the RI scope of work began in December 1987 with the release of the Mottolo Site Negotiation Support Document (NSD) prepared by Camp, Dresser & McKee Federal Programs Corporation (CDM-FPC) as a

contractor to EPA. This document was intended to be used by the EPA in negotiations with PRPs to ensure that an appropriate RI scope of work was developed, should a PRP consent to conduct the RI/FS. During consent agreement negotiations, EPA required that the NSD be used by Quinn's consultant, Balsam Environmental Consultants, Inc. (Balsam) as the basis for the development of the Mottolo Site RI/FS Work Plan. The Work Plan was submitted to EPA on March 24, 1988 and the Mottolo RI/FS officially commenced in May 1988 with the signing of a consent agreement between EPA and Quinn. The Work Plan became the basis for the Sampling and Analysis Plan section of the final Project Operations Plan, dated October 4, 1988, prepared by Balsam.

Monthly progress meetings commenced in June 1988 with the following parties: EPA; the New Hampshire Department of Environmental Services (NHDES); Balsam, the consulting engineering firm contracted by Quinn to conduct the RI/FS; and Stark & Peltonen, the law firm representing Quinn. These meetings were held to maintain open lines of communication between the key participants in the RI, provide up-to-date reports on work progress, and facilitate resolution of technical and administrative issues which arise in the course of conducting a RI/FS. A public meeting was also held in October 1988 to inform interested residents of Raymond and the surrounding communities of the RI/FS process and schedule.

The following report includes the findings of the RI portion of the RI/FS. The RI report is divided into seven sections. Section 1.0 provides background on the history of the site and local environmental conditions including land use, climate, soils, geology, and hydrology. Section 2.0 presents a detailed discussion of the investigations that comprised the RI and presents the data generated by each investigation. Section 3.0 provides an in depth summary of the physical characteristics of the study area based upon the field investigations discussed in Section 2.0, as well as selected data from investigations and analyses conducted by others prior to the RI. Section 4.0 describes the sources and extent of contamination detected in soil, sediment, air, surface water and ground water.

Section 5.0 includes descriptions of the dynamic processes which contribute to the fate and transport of the contaminants identified at the site. Section 6.0 summarizes the findings of the baseline risk assessment. The summary and conclusions are provided in Section 7.0.

## 1.1    REMEDIAL INVESTIGATION PURPOSE AND SCOPE

As stated in the National Contingency Plan (NCP), the purpose of the RI is to generate data to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives. The RI provides information to assess the risks to human health and the environment and to support the development, evaluation and selection of appropriate response alternatives. In summary, the objectives of the RI are to:

o    Describe the nature, source(s), extent, and distribution of contaminants;

o    Describe potential contaminant migration pathways;

o    Assess risks to public health and the environment posed by contaminants;

o    Gather data needed to identify feasible remedial actions, should they be necessary; and

o    Provide sufficient data to support remedy selection and design.

These objectives were met by implementing a phased remedial investigation which included the following components:

o    Preparation of a Project Operations Plan;

o    Air quality screening;

o    Geophysical investigations;

o    Three phases of soils and/or sediment investigations;

o    Monitoring well installation;

o    Three sampling rounds including collection of surface water and ground water samples; and

o    Data review and report preparation.

The data generated during each phase of the investigation were evaluated and incorporated into subsequent phases of the RI, as appropriate.

## 1.2    SITE BACKGROUND

### 1.2.1    Site Description

The Mottolo Superfund site is located on Blueberry Hill Road in southeastern Raymond, New Hampshire.  A locus map is provided as Figure 1-1.  For purposes of this report, the term "study area" will refer to the Mottolo property and surrounding area as shown in Figures 1-1 and 1-2.  The term "site area," used in this report, will refer to the southwestern quadrant of the Mottolo property, including the disposal area, as shown on Figures 1-2 and 1-3.

The Mottolo property is bounded by a rural residential neighborhood to the north, to the south and east by properties planned for residential development, and to the west by several residences and undeveloped land.  The only reported commercial activity in the study area was a former vehicle reclamation operation, located adjacent to the Exeter River and Blueberry Hill Road (see Figure 1-2), which operated from the mid-1960's through the early 1970's.  The Mottolo property comprises approximately 50 acres of primarily undeveloped land, divided approximately in half by a brook which originates beyond the southern property boundary and flows north through the property and eventually discharges to the Exeter River.  The brook is hereinafter referred to as "Brook A."  Approximately two acres of the property remain cleared from the former piggery operated on site, although some additional clearing of this area may have occurred during EPA waste removal operations.  The remainder of the parcel is undeveloped and heavily wooded.  The cleared area is divided by a drainage swale which flows from west to

east, discharging to Brook A (see Figure 1-3). The former piggery is located within the southern portion of the two-acre cleared area and was comprised of several structures. The first structure, located along the site access road, is an abandoned, one-story, wood and sheet metal shed which houses a dug well and a boiler. The second structure is an abandoned, one-story, wooden-frame building on a concrete slab, formerly used as the main piggery building. The remaining structures are two concrete slabs, located to the west and southwest of the main piggery building; these slabs were presumably the foundations for former one-story, wooden-frame buildings that were used in the piggery operations. A fill area containing piggery waste is located east of the main piggery building. Presumably pig waste was pushed from the piggery building with a tractor, resulting in the creation of the fill area. Figure 1-3 illustrates the majority of the Mottolo site area including the building structures, former drum disposal area, the drainage swale, Brook A, and areas cleared of tree growth by Mottolo and EPA.

## 1.2.2    Site History and Previous Investigations

Prior to the identification of hazardous materials disposal at the Mottolo site approximately eleven years ago, the site was used as a piggery. The piggery operation reportedly ended in the mid-1970's and it is estimated that disposal of hazardous wastes, primarily in steel drums and pails, occurred on site from approximately 1975 to 1979. The disposal material was used as fill to raise the grade of an area approximately one-quarter acre in size, located immediately north of the piggery building. Several investigations and activities were subsequently conducted to remove drums and to characterize the extent of contamination emanating from the disposal area. A chronological summary of key activities and investigations which occurred at the site is provided in Table 1-1, and a brief discussion of previous investigations is provided below. A detailed discussion of site history and findings of the prior investigations is contained in the Summary Assessment Report prepared by Balsam, dated February 26, 1988, and provided in Appendix A-1.

## Site Reporting

The site was reported in April 1979, when a local police officer observed drums on the site while hunting and subsequently filed a report describing site conditions. This report resulted in an investigation of the Mottolo property by the New Hampshire Bureau of Solid Waste Management (BSWM). The BSWM investigation identified a one-quarter acre open-face dump containing approximately thirty exposed 55-gallon drums (Department of Public Health Services (DPHS), 1987). This area is shown as the former disposal area on Figure 1-3. During the initial investigation in 1979, some of the drums were leaking and leachate was observed seeping into the swale at the toe of the disposal area. The swale flowed in an easterly direction and discharged into Brook A.

## WSPCC Preliminary Investigations

Water samples were collected from a leachate seep in April 1979 by the WSPCC. Aldehydes, ketones, alcohols, esters, and aliphatic compounds were identified in the samples. These compounds were reportedly similar to those listed on the exposed drum labels (DPHS, 1987). In May 1979, the WSPCC diverted the swale away from the toe of the drum disposal area to its present location, shown in Figure 1-3, in an effort to reduce the direct flow of leachate to the swale and subsequently Brook A. During the summer of 1979, the WSPCC constructed a sand and gravel berm along the northern edge of the drum disposal area to contain stormwater runoff from the disposal area and prevent the discharge of runoff directly to the swale. Runoff ponded by the bermed area most likely recharged to ground water.

In July 1979, the WSPCC installed three monitoring wells at the site. The WSPCC collected ground water samples from the three wells in August and October 1979. Results of both sampling rounds indicated the presence of chlorinated VOCs in samples from each well. Details on the compounds detected are provided in Appendix A-1. During the fall of 1979, the WSPCC also sampled

several residential water supply wells in the vicinity of the Mottolo site. VOCs were not identified in residential well samples.

**EPA Preliminary Investigation**

The EPA became involved after the WSPCC collected information indicating the potential for environmental and health impacts associated with the site. In April 1980, EPA personnel conducted a site reconnaissance to assess general site conditions. The reconnaissance survey included a site inspection and air monitoring using a photoionization detector (PID). VOCs were not identified in ambient air by the PID above background levels (0-1 parts per million (ppm)) except in the vicinity of exposed 55-gallon drums where PID responses ranged between 0 to 20 ppm. EPA's Technical Assistance Team (TAT) obtained ground water samples from the three wells previously installed by the WSPCC. Surface water samples were also collected from Brook A, the swale, and an impoundment formed along the berm at the toe of the disposal area. Results of the analyses indicated that several VOCs were present in ground water and surface water discharging from the disposal area into Brook A.

**GHR/GZA Investigation**

In April 1980, the WSPCC retained GHR Engineering Corporation (GHR) of New Bedford, Massachusetts to perform an engineering and hydrogeologic investigation of the Mottolo site. The objectives of the GHR investigation were to define the degree and extent of on-site contamination, characterize hydrogeologic conditions controlling contaminant migration from the disposal area, identify potential remedial approaches, and evaluate remedial costs. GHR subcontracted the hydrogeologic phase of the investigation to Goldberg-Zoino & Associates, Inc. (GZA) of Newton Upper Falls, Massachusetts. The GHR/GZA investigation included the advancement of two deep and five shallow soil borings, soil sampling, packer pressure testing of site bedrock, excavation of twelve test pits, installation of six monitoring wells and two multi-level ground water sampling systems, and

periodic sampling of surface water and ground water between May and December, 1980. This investigation was conducted concurrently with an EPA emergency response action discussed below.

Significant findings of the GHR/GZA hydrogeologic investigation (GHR/GZA, 1981) were as follows:

o    The overburden material was described as a glacial till up to 15-feet thick consisting of poorly sorted silt, sand, gravel, cobbles, and boulders. Up to 6-feet of stratified deposits composed of fine to coarse sand and silty sand were identified near Brook A.

o    The bedrock formation underlying the site was identified as a biotite schist that appeared to be weathered and fractured at certain locations and depths.

o    The direction of ground water flow on the site in the overburden was determined to be in an easterly direction toward Brook A.

o    Site ground water in the overburden and bedrock was reported as contaminated with VOCs and selected inorganic compounds, with the highest concentrations of contaminants observed in the overburden.

o    The areal distribution of the contaminant plume in ground water was described as the area between the disposal area and Brook A.

o    A correlation between bedrock and overburden contamination was observed, suggesting a hydraulic connection between the two aquifers.

o    The volume of contaminated soil on site was estimated to be from 8,000 to 12,000 cubic yards.

o    It was recommended that further study be undertaken to characterize subsurface conditions at the site.

**EPA Emergency Response**

In September 1980, EPA prepared the site for exhumation, staging, and removal of buried drums. The area north of the drainage swale and the berm constructed along the toe of the disposal area in 1979 were cleared and graded to construct

temporary staging areas for the excavated wastes. As the containers of waste were excavated, they were staged on site for characterization. Staging areas are shown on Figure 1-3. Analyses for numerous compounds including PCBs and pesticides were reportedly performed on samples from each container. Toluene, methyl ethyl ketone, alcohols, acetates, chromates, lead, zinc, lacquers, turpentine, animal fats, chlorinated compounds, and packaged laboratory chemicals were identified in drums and pails removed from the site. No evidence of pesticides, herbicides, PCBs, or oils was detected (WSPCC, 1986).

After the contents of each container were classified, the containers were moved to staging areas in and around the piggery building and the concrete slabs and stored according to classification. Approximately 1,600 55-gallon drums and 5-gallon pails were excavated and characterized during this operation. Although most of the drums appeared to be dented or partially crushed, EPA estimated that eighty-three 55-gallon drums and seven 5-gallon pails were empty when exhumed.

Authorization for removal of the exhumed wastes from the site was not obtained until November 1981. Waste removal began approximately one month later, on December 14, 1981, and was completed on February 4, 1982. Many of the containers were repacked into 80-gallon recovery drums prior to transportation off site.

Approximately 160 cubic yards of contaminated soil, drum parts, and plastic sheeting used in the staging areas were also transported off site for disposal at this time. After the removal operation was completed, the berm north of the drum disposal area was reportedly reconstructed and the excavated area was partially regraded and seeded. The removal operation was described in an EPA On-Scene Coordinator (OSC) Report (OSC report, undated).

## WSPCC Investigation

Between March 1985 and June 1986, the WSPCC conducted a hydrogeologic investigation of the Mottolo site. The purpose of the investigation was to obtain additional information to describe the site and areas of contamination and to identify receptors potentially at risk from the migration of contaminants from the site. The investigation included a fracture fabric analysis of bedrock in the site area, geophysical surveys, installation of ten monitoring wells, measurement of ground water and surface water elevations, and sampling of monitoring wells and nearby surface waters (WSPCC, 1986).

Significant conclusions from the WSPCC investigation are summarized below:

o   Bedrock fracture lineaments were not observed in aerial photography passing through the site, but the orientation of bedrock fractures was observed in several bedrock exposures near the site.

o   A magnetic survey did not identify buried metallic objects near the piggery building or indicate structural geologic features exhibiting a significant magnetic signature in the Brook A valley east of the site.

o   Less than 20 feet of overburden sediments were reported to overlie bedrock on site. A bedrock divide was identified near the northwest corner of the piggery building. Surficial geology was described as glacial till overlying bedrock in the upland areas and glacial stratified drift overlying bedrock in the Brook A valley.

o   An area of overburden ground water containing VOCs was delineated in an area measuring 75 to 100 feet in width and was described as extending from the former drum disposal area toward Brook A.

o   A second area of ground water contamination of unknown extent was identified in the overburden and bedrock approximately 230 feet north of the former disposal area and adjacent to Brook A.

o   The swale was reported to be impacted by VOC-contaminated ground water.

o   Brook A exhibited decreasing VOC concentrations with distance downstream from the swale confluence.

o     VOCs identified in ground water included aromatic and aliphatic compounds, ketones, and tetrahydrofuran.

o     An upward component of ground water flow, from the overburden in to Brook A, was reported.

o     Bedrock beneath the site was described as weathered and fractured at various depths at different locations on site and consisted of biotite schist, quartzite, and granite.

o     Ground water quality downgradient of the former disposal area showed increased concentrations of iron and manganese when compared to ground water quality from a dug well upgradient of the former disposal area. Concentrations of arsenic, lead, and zinc were also reported to be slightly higher than concentrations in ground water samples from the dug well.

WSPCC concluded that the site posed a potential risk to residential water supplies and recommended the performance of further investigations and remediation of the site in accordance with the NCP.

**New Hampshire Public Health Services Environmental Health Risk Assessment**

Subsequent to the WSPCC hydrogeologic investigation, the State of New Hampshire Department of Public Health Services (DPHS) initiated a draft Health Risk Assessment for the site in May 1987, although a final document was not prepared because a risk assessment was included with the RI/FS scope of work. The objective of the assessment was to preliminarily summarize potential health effects associated with potential exposures to contaminants present at the site. The study included an exposure assessment, a hazard identification/dose-response assessment, and risk characterization.

The DPHS found that the site was readily accessible and should, at a minimum, be posted to discourage unauthorized entry. The potential risk to area residents from exposure to contaminated water supplies was also addressed. The DPHS concluded that there was no present risk posed by consumption of ground water,

since analyses of ground water samples collected from residential wells in the site area did not indicate the presence of contamination at that time. Future risk associated with the use of contaminated ground water was also estimated by performing calculations of increased lifetime cancer risks using unit risk values derived by the EPA Carcinogenic Assessment Group. Additional studies to better define areas of contamination were recommended, along with continued monitoring of residential wells.

**WSPCC/NHDES Residential Well Sampling**

Since 1979, selected residential wells in the vicinity of the site have been sampled periodically and analyzed for VOCs by the NHDES (formerly WSPCC). VOCs were not detected in residential well samples until the spring of 1986 and fall of 1987 when up to 15 parts per billion (ppb) of total VOCs were identified in several water samples from recently installed domestic wells. The VOC most frequently identified was tetrahydrofuran, although 1,1,1-trichloroethane, meta-xylene, and methyl ethyl ketone have also been reported in some samples. Further discussion of residential well water quality is provided in Section 2.7.

## 1.3    STUDY AREA BACKGROUND

### 1.3.1    Local Land Use and Demography

The Mottolo site is located along the southeastern boundary of the rural, residential community of Raymond, New Hampshire. Raymond has a population of approximately 9,500. The smaller towns of Chester and Freemont are located south and east of the Mottolo site and have populations of 2,600 and 2,000, respectively.

The land adjacent to the Mottolo site is zoned for residential use by the town of Raymond. Land use restrictions in Freemont are decided on a case-by-case basis, though current local development trends would indicate that land near the study

area could be developed for residential use. Nearby land in Chester is zoned residential. A land use map for the study area is provided as Figure 1-4. The majority of the development in the vicinity of the Mottolo site is to the north and is characterized by single family homes, the majority of which were constructed between 1981 and 1987. Several homes are also located west of the site, along Blueberry Hill Road. Land to the south and east of the Mottolo property is currently being prepared for residential development. Tax maps and development plans were used to compile Figure 1-5 which indicates approximate property boundaries and currently planned subdivision lots in the study area.

## 1.3.2    Climate

Climatological information for the Mottolo site was derived from the Revised Uniform Summary of Surface Weather Observations generated by the Data Processing Branch of the Air Weather Service. The nearest identified climatological station is located approximately 26 miles east of the Mottolo site, at Pease Air Force Base in Portsmouth, New Hampshire. Information provided below is summarized from this source and is based upon 8035 observations recorded between 1957 and 1979.

The mean annual precipitation for the period of record was 43.9 inches, while the mean maximum 24-hour rainfall was 3.3 inches. The mean annual snowfall was 74.9 inches and the mean maximum 24-hour snowfall was 12.2 inches. The National Climatic Data Center reported that mean annual precipitation in Concord, New Hampshire was 36.5 inches, indicating an inland location, such as the Mottolo site, is likely to have slightly less precipitation than a coastal location, such as Pease Air Force Base.

Extreme maximum and minimum mean temperatures for the period of record were 93.8 and minus 5.9 degrees Fahrenheit, respectively, while the mean annual temperature was 47.8 degrees Fahrenheit. The wind direction is typically from the west or west-northwest with a mean speed of 7.4 knots. Information

concerning surface winds was summarized from 1967 through 1970 and 1973 through 1979, and the data are based on a total of 87,616 observations.

## 1.3.3    Environmental Setting

### Topography

The topography in the Raymond area is typical of glaciated regions of southern New Hampshire which are characterized by low lying hills and relatively gradual slopes. Land elevation in the vicinity of the Mottolo study area ranges from approximately 230 feet above mean sea level (MSL) in the upland area to 165 feet MSL along the Brook A valley. The majority of the former working area of the site, which contains the piggery building and pads, as shown on Figure 1-3, is considered to be in the upland area for the purposes of this report. The site topography, shown in Figure 1-3, slopes approximately 10 degrees to the north from the piggery building across the former disposal area to the swale. The topography east of the piggery building slopes downward at approximately 23 degrees to form the valley which contains Brook A. The cleared area north of the swale slopes approximately 5 degrees south toward the swale.

### Soils

The Soil Conservation Service (SCS), has described and mapped surficial soils of Rockingham County, New Hampshire (SCS, 1983). Five primary soil types are present in the Mottolo site area including:

o    A complex of Chatfield, Hollis and Canton soils;

o    Walpole very fine sandy loam; and

o    Greenwood mucky peat.

The Mottolo property area is largely covered by intermingled soils of the Chatfield, Hollis and Canton complex of fine sandy loams with slopes ranging from 3 to 35 percent. These soils are typically found in upland areas and along hillslopes of the site. Regardless of the slope, soil permeability is described as moderately rapid and the soil drainage classification ranges from somewhat excessive to well drained. These soils are described as suitable either for use as woodland or for development, although soils with the greater slopes may be poorly suited for development.

The Walpole fine sandy loam is found on 3 to 8 percent slopes within the Mottolo property, and primarily in drainageways such as along the banks of Brook A. Drainage classification is described as poor, with moderately rapid permeability. These soils are suited for use as woodland but not for development.

Greenwood mucky peat is typically found within basins, hollows, and drainageways, and soils of this type are described for wetlands to the southeast of the site area. Characteristics of the soil type include a moderate permeability and a drainage classification of very poor. The soil is described as unsuitable for use as woodland or for development.

**Regional Geology**

The typical stratigraphic sequence in the vicinity of the Mottolo study area consists of bedrock overlain by glacial drift deposits of Pleistocene age which are generally overlain by Holocene alluvial and swamp deposits. Bedrock in the vicinity of the study area commonly consists of biotite schists, biotite granofels, and quartzite of the Berwick Formation. The Berwick Formation is bounded to the west by the Massabesic Gneiss Complex and to the east by Merrimack Group metasedimentary rocks of the Elliot and Kittery Formations. The trace of the axial surface of the Massabesic Anticlinorium is approximately 7 miles northwest of the site and strikes about 48 to 52 degrees east through that area. These units are cut by several northeast trending fault zones, including the Flint Hill Fault

Zone and the Campbell Hill/Hall Mountain Fault Zone which can both be traced northwest of the Mottolo site. The trace of the Campbell Hill/Hall Mountain Fault Zone is approximately 15 miles northwest of the site area, while the Flint Hill Fault Zone is approximately 5 miles northwest of the Mottolo site.

Glacial drift deposits in southeastern New Hampshire vary in thickness and commonly consist of glacial till or glacial outwash. In the region, where present, glacial till forms an irregular, discontinuous layer over the bedrock ranging in thickness from approximately 0 to 150 feet (Mayewski and Birch, 1984). The till is described as an unsorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles, and boulders, with some gravel (Gephart, 1987). Glacial outwash deposits are typically less than 40 feet thick in this region (Gephart, 1987). These deposits, which generally consist of stratified boulders, cobbles, pebbles, sand and silt, are sediments deposited by glacial meltwater streams (glaciofluvial) or sediments deposited in glacial lake environments (glaciolacustrine).

The Holocene age deposits are usually associated with swamp, river, and lake environments. These deposits consist of sand, silt, and gravel which have been deposited along present-day rivers and streams; and muck, peat, silt, sand, and clays associated with poorly drained swamp or lake environments. These deposits are typically 5 to 10 feet thick, but are occasionally found as thick as 30 feet (Gephart, 1987).

The regional geologic conditions described above are consistent with geologic data obtained during this RI. A detailed discussion of the study area geology is provided in Sections 2.0 and 3.0.

## 1.3.4    Hydrology Summary

The Mottolo site is located within the Exeter River drainage basin. The Exeter River nearly circumscribes the Mottolo site. The river is approximately 2,000 feet northwest of the site at its closest point (Figure 1-6). Based upon topographic and

hydrologic information, regional surface water and ground water are ultimately expected to discharge to the Exeter River. Further information concerning regional hydrology is provided in Section 3.0.

Brook A is a perennial stream that flows north across the Mottolo property, draining approximately 285 acres at its confluence with the Exeter River. The drainage basin corresponding to this area is shown in Figure 1-6. The headwaters of Brook A originate in wetlands located immediately south and southeast of the Mottolo site. The relatively steep topography to the west and east of the brook in the vicinity of the Mottolo site indicates that the brook is the local discharge zone for local overburden ground water and very likely the discharge zone for local bedrock ground water. This relationship is discussed further in Section 3.0.

At the base of the former disposal area, an ephemeral stream is located in a swale which drains approximately four acres of the undeveloped woodland between the cleared site area and Blueberry Hill Road. The swale also receives surface water runoff from the cleared areas to the north and south. The stream flows easterly across the site and down the valley wall into Brook A (Figure 1-3). Drainage patterns in the site vicinity suggest that surface water drainage is generally toward Brook A on either side of the brook.

# BALSAM

ENVIRONMENTAL CONSULTANTS, INC.

Engineering, Environmental Science & Industrial Hygiene

# 2.0 STUDY AREA INVESTIGATIONS

Several investigations were conducted during the RI to characterize the site and study areas and describe the nature, source(s), and extent of contamination; to identify potential contaminant pathways; to provide data necessary to assess potential risks to public health and the environment; and to provide data sufficient to identify feasible remedial actions, select a remedy, and support remedial design requirements. These investigations included:

o   An assessment of surficial features, including a review of historical aerial photographs and a bedrock outcrop study.

o   Geophysical investigations to obtain information on soil stratigraphy and study area stratigraphy and to assess potential areas of ground water and soil contamination.

o   Soil investigations, including a soil gas sampling program and a three-phase soil boring program, to obtain information on soil stratigraphy and the nature and extent of contamination in site area soil.

o   Ground water and surface water investigations, including the installation of on-site and off-site monitoring wells, aquifer testing, ground water and surface water sampling and elevation measurements, sediment sampling, stream gauging, a baseflow analysis and a wetlands assessment, to obtain information on study area hydrogeology and the nature and extent of contamination in these media and to assess contaminant transport and fate, migration pathways, and receptors in the study area.

o   Residential well water collection and analysis by the New Hampshire Department of Environmental Services (NHDES) and Balsam to assess ground water quality in residential areas north, south, and west of the Mottolo site.

o   Air quality monitoring to assess whether concentrations of contaminants were present in ambient air in the site area.

A discussion of the procedures used to perform these investigations and the data generated are presented in the following sections.

## 2.1    SURFACE FEATURES

### 2.1.1    Topographic Survey and Base Map Development

Ground surface topographic maps were developed for the Mottolo study area by
Eastern Topographics of Ossipee, New Hampshire based upon aerial photography
taken on March 30, 1988. Ground control surveying was conducted in July 1988
to obtain the datum control points necessary to develop a study area base map at
a scale of 1 inch equals 100 feet and a site area map at a scale of 1 inch equals
40 feet. Topographic map elevations are relative to mean sea level according to a
United States Geologic and Geodetic Survey datum. The topographic base maps
include such features as buildings, paved areas, surface water bodies, utility poles,
approximate Mottolo property boundaries, and large surface features such as
boulders or other man-made features. The locations of soil borings and monitoring
wells were surveyed and added to the topographic base map as necessary during
the course of the RI. The locations of study area property boundaries were added
to the base maps by Balsam using town of Raymond tax maps and development
plans obtained from local developers. The approximate locations of residential
wells and septic disposal systems in the Blueberry Hill neighborhood were also
added to the base map based upon visual observations by Balsam as well as
interviews with home owners.

### 2.1.2    Aerial Photograph Review

In order to identify changes in land use or activities which would assist in
understanding study area history, a search for historical aerial photographic
coverage of the Mottolo site was conducted. Aerial photographic coverage of the
study area was identified and obtained for several dates between April 23, 1966
and March 30, 1988. A summary of aerial photographs reviewed and comments
regarding changes visible in the study area between photograph dates is provided
in Table 2-1. Based upon review of these photographs, the site was undeveloped
in 1966 with piggery operations beginning sometime between 1966 and 1973.

Other significant historical activities related to drum disposal or removal operations were not identified in the aerial photographs reviewed.

### 2.1.3    Bedrock Outcrop Study

A bedrock outcrop study was conducted by Balsam in November 1988 to provide information on bedrock characteristics that may influence the movement of ground water through bedrock within the study area. Structural data were collected at eleven outcrops in the study area and compared with a fracture trace analysis, dated March 22, 1985, conducted by BCI Geonetics Inc. (BCI) for the WSPCC study (WSPCC, 1986). Data concerning joint orientation, foliation azimuth, dip angle and direction, and lithologic characteristics of the bedrock were collected by Balsam personnel using a Brunton compass and hand lens. The bedrock outcrops were identified in readily accessible areas within the study area and are shown on Figure 2-1.

**Data Presentation**

Lithologies present in the study area include several members of the Berwick Formation and pegmatitic intrusions. Rock types observed include well-foliated, fine-grained, purple-gray biotite granofels with calcareous lenses; biotite schist; migmatitic biotite granofels and quartzo-feldspathic pegmatites.

Measurements of foliation and joint strike and dip at the identified outcrops are presented in Table 2-2. Strike is defined as the compass orientation of the joint or foliation plane as it intersects a horizontal plane. Dip is the angle that the joint or foliation makes with a horizontal plane measured perpendicular to the strike direction. Measurements are recorded with the strike direction first, followed by the dip angle and the general dip direction, for example, 20° (strike direction), 70° (dip angle), NW (dip direction). Joint measurements were organized by set based upon similar strike direction, dip direction, and dip angle. Strike of joints and dip angles was averaged and results are also reported in Table 2-2.

Variations in foliation orientation could be due to localized deformation effects from pegmatitic intrusions, folding, or proximity to the Flint Hill fault zone. Foliation data are plotted on a sterographic net shown in Figure 2-2. Joint orientations are shown on a rose diagram in Figure 2-3.

The outcrops studied appeared to be moderately fractured. Slickensides were observed on some joint surfaces, most notably at outcrop number 9. Weathering of joint surfaces and, in some cases, foliation surfaces, was observed at several locations. Iron staining and clay mineralization were observed along several joint surfaces. Pegmatitic intrusions were generally weathered and hydrothermal alteration of adjacent rock types was observed.

**Data Interpretation**

Based upon a review of foliation data shown in Figure 2-2, there is a preferred foliation orientation of approximately 30°, 70° SE. Joint surface orientations observed in the study area indicate five sets of preferred joint orientations at approximately 20°,70°NW; 40°,65°SE; 100°,80°N; 110°,65°SW; and 140°,80°NE (Table 2-2).

Results of the BCI fracture trace analysis conducted in the study area indicate there were four principle fracture orientations in the study area based primarily upon an assessment of aerial photographs. These strike orientations are 38° to 44°, 86°, 130°, and 174° and compare reasonably well with the principal orientations identified by Balsam, with the exception of the 174° orientation.

The occurrence of weathered joint foliation and fracture surfaces indicates that the structures likely act as pathways for ground water flow near the site. Portions of the Exeter River and Brook A are approximately parallel to the orientation of some joint fracture orientations suggested by BCI and Balsam fracture analyses. Based upon this information, the courses of Brook A and the Exeter River may be structurally influenced.

## 2.2    GEOPHYSICAL INVESTIGATIONS

Geophysical surveys were conducted by Weston Geophysical Corporation (Weston) under subcontract to Balsam from October 31, 1988 through November 10, 1988 and by Hager-Richter Geoscience, Inc. (Hager-Richter) in September 1989. Weston conducted seismic refraction, electromagnetic terrain conductivity, and proton precession magnetometry surveys to assist in identifying lithologic units, potential subsurface contamination, and bedrock fracture zones that may influence ground water movement in the study area. Hager-Richter conducted a one-day seismic refraction survey near the southern property boundary to obtain information on overburden thickness and bedrock surface topography in this area. The Weston data were used to assist in selecting the locations of soil borings and monitoring wells installed from November 1988 through January 1989, while the Hager-Richter geophysical data were used to support the selection of locations for monitoring wells installed in September 1989. The Weston and Hager-Richter reports, referenced in the following discussion, are provided as Appendices B-1 and B-2, respectively.

Development of the RI geophysical investigation plan was primarily based upon results of geophysical surveys conducted at the site in 1981 and 1985 under the direction of the NHDES. The past surveys conducted within the site area included seismic refraction, electromagnetic terrain conductivity, proton precession magnetometry, borehole resistivity, and electrical resistivity.

Final locations of the geophysical investigation survey lines used during the RI were selected based upon review of the following:

o   Fracture and joint orientations measured by Balsam at bedrock outcrops in the study area,

o   Previous lineament analyses conducted by BCI for the NHDES,

o   Regional geologic information,

o  Previous geophysical investigation data,

o  Available ground water quality data, and

o  Current study area access conditions.

Survey lines were generally aligned perpendicular and parallel to the major joint and fracture orientations which had been identified in previous studies in order to improve the potential for survey techniques to assess these features.

Objectives of the seismic refraction surveys were to characterize the lithologic properties of the strata, estimate depth to bedrock, and possibly identify the presence of bedrock fracture zones both on site and off site. Two methods of electromagnetic terrain conductivity surveying were conducted; a shallow conductivity survey was performed using a Geonics EM-31, while deeper conductivity surveys were performed using a Geonics EM-34 in both the horizontal and vertical dipole modes. The EM-31 survey was conducted on site in the former drum staging area north of the swale, near the swale, and adjacent to Brook A, with the objective of possibly detecting the presence of a ground water plume containing dissolved conductive constituents (e.g., iron) in saturated overburden. It was not anticipated that VOCs would be detected in ground water by this geophysical method due to the low concentrations of VOCs in ground water and the masking effect of ground water and conductive subsurface materials. An EM-34 survey was conducted both on site and off site to detect the possible presence of water-filled fractures in the bedrock which could provide migration routes for ground water and to supplement findings of the seismic refraction survey. Proton precession magnetometry survey data were obtained to supplement seismic refraction and electromagnetic terrain conductivity data where the presence of bedrock fracture zones was indicated. Locations where each method was employed are shown on Figure 2-4.

A discussion of general field procedures used during the geophysical surveys and data are provided below. Additional detail is provided in the Weston and Hager-Richter reports attached as Appendices B-1 and B-2, respectively.

## 2.2.1 Weston Seismic Refraction Survey

A total of approximately 6,400 linear feet of seismic refraction profiling was performed along nine transects within the site area and in the residential neighborhood to the north of the site. Profile transects are shown on Figure 2-4. Seismic refraction profiles and raw travel time data are provided in the Weston report.

Seismic refraction surveys within the site area were performed with 400-foot spread lengths, 10- and 20-foot geophone spacings and five shot points per spread. A schematic diagram of the geophone spread array is shown on Figure 2-5. Seismic travel times were recorded in milliseconds using a WesComp 24 Trace Analog System. A discussion of the theory of refraction profiling is provided in the Weston report. On-site seismic refraction profiles are presented on Figure 4 of the Weston report (Appendix B-1).

Seismic source energy was generated using small explosive charges during on-site operations. One-third to one stick of Kinepac explosive was buried at shot points to depths ranging between 1 foot and 3.5 feet below ground surface. Wooden stakes were used to pack charges in the ground.

Seismic refraction surveys were conducted in residential areas using 250-foot spread lengths, 10-foot geophone spacings, and five shot points per spread. Figure 2-5 illustrates the geophone spread array. Seismic energy was generated using a Betsy seisgun (a shotgun mounted vertically with the barrel-end pointed down) in residential areas. The barrel was surrounded by a 2-foot-diameter rubber

tire to muffle the sound. Seismic waves were generated by firing the shotgun at the ground. Off-site refraction profiles are provided on Figure 5 of the Weston report (Appendix B-1).

## 2.2.2 Hager-Richter Seismic Refraction Survey

A total of approximately 800 linear feet of seismic refraction surveying was conducted near the southern Mottolo property boundary by Hager-Richter along survey lines SL1, SL2, SL3, and SL4, as shown on Figure 2-4. The objective of this survey was to obtain information on overburden thickness and bedrock surface topography to assist in locating two additional monitoring well couplets in the southern boundary area.

Seismic refraction profiles and raw travel times are provided in the Hager-Richter report (Appendix B-2). Seismic refraction surveys within the southern boundary area were performed with 110-foot spread lengths and 10-foot geophone spacings with six shot points per spread. Figure 2-5 illustrates the geophone spread array. An EG&G Model ES1225 Multiple Channel Signal Enhancement Seismograph was used to record signals. Seismic energy for the survey was generated by hitting a steel baseplate with a ten pound sledge hammer. The seismograph recorded signals for 100 milliseconds after each shot. Successive signals were accumulated by adding successive readings from the 12 channels to decrease the effects of noise and enhance signal strength.

## 2.2.3 Electromagnetic Terrain Conductivity Surveys

Electromagnetic terrain conductivity (EM) survey techniques were used on site and in residential areas. Approximately 5,600 linear feet of EM-31 surveying and 6,100 linear feet of EM-34 surveying were conducted. A description of the theory of EM surveying is provided in the Weston report (Appendix B-1).

EM-31 surveys were conducted in the former disposal area and staging areas and in the vicinity of Brook A, as shown in Figure 2-4. A Geonics EM-31 conductivity meter with a fixed intercoil spacing of 3.7 meters and a continuous chart recorder was used to acquire EM values in the horizontal dipole mode. The EM-31 measures average earth conductivity to a depth of approximately 15 to 20 feet beneath ground surface. A conductivity contour map (Weston Figure 6) and raw data (Weston Appendix B) are provided in the Weston report (Appendix B-1).

A Geonics EM-34 terrain conductivity meter with a coil separation of 10 meters was used in both the horizontal and vertical dipole modes to collect data in several locations, both on and off site, as shown in Figure 2-4. The EM-34 survey was used in conjunction with the seismic refraction survey to assess the presence of significant water-bearing fractures which may exhibit an increase in conductivity. The effective depth of penetration with the EM-34 method with 10 meter coil separations is approximately 25 and 50 feet beneath ground surface in the horizontal and vertical dipole modes, respectively. Measurements were recorded at 25-foot intervals along survey lines. Conductivity profiles (Weston Figure 7) and raw data (Weston Appendix B) are provided in the Weston report (Appendix B-1).

### 2.2.4    Proton Precession Magnetometry Survey

A Geonics proton precession field magnetometer was used to collect approximately 1800 linear feet of magnetic field measurements. Magnetic surveys were conducted in selected areas along each on-site traverse where seismic refraction or EM-34 data indicated the potential presence of an anomalous bedrock feature. Magnetic surveys in the residential area were limited to a small portion of Line H due to the presence of cultural features such as power lines which interfere with magnetic field measurements. Magnetic survey coverage is summarized on Figure 2-4.

Measurements were recorded in units of gammas at 10-foot intervals along the survey lines. Base station readings were measured both prior to and after each

survey line was completed to assess diurnal variations in the earth's magnetic field. At least three readings were taken at each survey point and values were averaged by field personnel to obtain the reported value. Magnetic profiles (Weston Figure 8) and raw data (Weston Appendix C) are provided in the Weston report (Appendix B-1).

## 2.2.5    Data Interpretation

### Seismic Refraction

Results of the on-site seismic refraction surveys suggest the presence of three distinct velocity layers:  1) unsaturated unconsolidated sediments, 2) saturated unconsolidated sediments, and 3) bedrock.  Seismic velocity in the uppermost zone ranged from 1000 to 2100 feet/second and is representative of relatively unconsolidated, dry sediments.  The water table surface is represented by the interface between the uppermost velocity zone and a middle zone, with a seismic velocity on the order of 5000 feet/second.  Glacial till is most likely located in this middle zone and, in most cases, cannot be distinguished from less consolidated saturated soil.

Seismic refraction wave velocities in bedrock on site ranged from 11,000 to 16,000 feet/second and are typical of slightly weathered or non-massive bedrock. Interpretation of the on-site seismic refraction data suggests that there are lower velocity zones in the bedrock which exhibited velocities less than 14,000 feet/second along lines A, B, and D on the western side of Brook A.  These areas are identified as a "possible fracture zone" on Figure 4 of the Weston report (Appendix B-1).  These low velocity zones appear to coincide with a significant decrease in the bedrock elevation or a bedrock trough which could represent changes in bedrock lithology or a fracture zone.

Seismic refraction profiles indicate that overburden thickness ranges from 0 to approximately 30 feet in the site area.  A bedrock outcrop approximately 20 feet

north of the northwest corner of the piggery building represents the highest topographic elevation in the piggery area. Line D begins 30 feet east of this point, where seismic refraction data indicate the depth to bedrock is approximately 6 feet. From this point traveling northeast along line D, the overburden thickens to approximately 15 feet in the former disposal area and decreases to approximately 5 feet at the swale. The area appears to be underlain by low velocity, unconsolidated, unsaturated and saturated deposits. In general, bedrock in the former drum staging/sampling area north of the swale appears to be less than 5 feet below ground surface. West of the former drum staging/sampling area along line A, the overburden thickness increases to approximately 20 feet. East of the former disposal area along line A and the swale, the overburden thickens to approximately 10 feet and then decreases to less than 5 feet at Brook A. Within the site area east of Brook A, along lines A, B and C, the overburden appears to thicken to 20 to 30 feet with the exception of the east end of line C, where the depth to bedrock is approximately 12 feet. West of Brook A and north of the former staging area, the overburden thickness is generally between 5 and 10 feet. Seismic refraction data collected along lines A, B, and C indicate that the depth to bedrock beneath Brook A is approximately 5 to 10 feet. In general, overburden thickness indicated by seismic refraction data correlates well with data from borings completed in the vicinity of traverse locations.

Troughs or irregularities in the bedrock surface adjacent to Brook A are exceptions to these trends. These troughs may represent buried stream channels, fracture zones, or lithologic units which have weathered preferentially. The low velocity zones and bedrock troughs are aligned with the north-south orientation of Brook A and may represent the presence of a significant geologic feature.

Results of off-site seismic refraction surveying suggest the presence of three distinctive velocity layers, similar to the on-site interpretation. Data indicate that overburden consists of unconsolidated, unsaturated sediments, with seismic velocities ranging from 1200 to 2000 feet/second, and saturated, unconsolidated

sediments, with seismic wave velocities of approximately 5000 feet/second. Seismic refraction wave velocities in bedrock at off-site locations ranged from 10,000 feet/second to 16,000 feet/second.

Depth to bedrock indicated by seismic refraction data in the residential area is typically 5 to 15 feet. Exceptions were encountered along lines H and I, where the overburden thickness was shown to be greater than 15 feet. A bedrock trough was also indicated beneath Brook A, along line E, where overburden is approximately 25 feet thick. In general, the depth to bedrock increases to the north toward Jennifer Lane and in the vicinity of Brook A.

Bedrock velocities obtained at off-site locations were generally lower than those obtained on site. This could be due to a difference in lithology, increased weathering, or fracturing of the bedrock. Bedrock velocities less than 13,500 feet/second along line H could indicate that the survey line is parallel to the strike of a northwest-southeast trending structural feature such as a joint. Seismic energy propagates slowly along the strike of a joint, but propagates quickly in a direction perpendicular to a joint. This concept is corroborated by the higher bedrock velocities obtained along line G which is perpendicular to line H. At the intersection of Jennifer Lane and Huckleberry Road, where lines G and H intersect, the bedrock velocity obtained at line G was 14,000 feet/second; whereas, the bedrock velocity obtained in the survey of line H was 11,000 feet/second for the same zone. This suggests that the strike of a structural feature present in the area may be similar to the orientation of line H. Lower seismic velocities measured in bedrock along the north and south ends of line F and line E may also represent either northwest-southeast trending fracture zones or changes in bedrock lithology.

The Hager-Richter seismic refraction survey profiles suggest that bedrock depths are generally less than 20 feet below ground surface in the survey area south of the southern property boundary. In some cases, a saturated zone or water table was not detected during seismic refraction surveys, presumably due to a higher

bedrock surface elevation and thin overburden thickness. This occurred in the eastern half of the survey area along lines SL1, SL2, and SL4. Interpretation of seismic line SL1 suggests the possible presence of a bedrock trough or fracture zone. Bedrock velocities in this area are interpreted to be lower than along lines SL2, SL3, SL4, and along the eastern portion of SL1.

**Electromagnetic Terrain Conductivity**

EM surveys did not indicate the presence of significant anomalies related to contaminant plumes or geologic features. The variability in depths to bedrock and the water table throughout the study area very likely contributed to the minor fluctuations in conductivity values observed.

Background conductivity values measured during the EM-31 surveys generally ranged from 0.5 to 1.5 millimhos per meter (mmhos/meter). Weston indicated these values are considered typical of saturated ground water present in sand and gravel deposits. Values measured along line A (0+00 to 4+00) and line 11 (shown in the Weston report, Appendix B-1) are typical of background readings for this site. In several areas, measurements greater than 1.5 mmhos/meter and reverse polarity (RP) readings, typically caused by metallic objects, were recorded. These measurements appear to be associated with metallic debris such as fence posts and drum parts, steel protective casings, metal well and piezometer casings, the presence of saturated sediments, surface water, and possibly ground water with slightly higher conductivities than at background locations. Reverse polarity values were recorded in the former disposal area, in the piggery waste pile area, and the former drum staging area north of the swale. Surficial metallic debris which would contribute to the reverse polarity readings was observed in each of these areas during field activities. Conductivity values greater than 1.5 mmhos/meter were measured in the former disposal area, along the swale to Brook A, the piggery waste pile area, a zone from the waste pile to Brook A, and along Brook A. These elevated conductivities may represent two slightly conductive ground water plumes extending from the former disposal area and the

piggery waste pile area to Brook A. However, saturated soils are also present in the zones extending to Brook A, and this condition may also result in the slightly elevated conductivities measured. Small fluctuations in conductivity values are typically due to changes in subsurface materials and the depth to ground water and bedrock. Elevated conductivities observed along Brook A are likely due to the presence of surface water. Weston indicated conductive contaminated ground water plumes are commonly detected as anomalies greater than 10 mmhos/meter in the region. Based upon this information, the EM-31 survey did not indicate the presence of a significant conductive ground water plume.

Background conductivity values collected using the EM-34 survey technique generally ranged from 1 to 2.5 mmhos/meter on site and from 2 to 3.5 mmhos/meter off site. Overall, conductivity measurements in the vertical dipole mode were slightly higher than in the horizontal dipole mode. This is most likely due to a greater thickness of saturated sediments (i.e., conductive material) being measured in the deeper penetrating vertical dipole mode than the horizontal dipole mode. Conductivity values recorded in the residential neighborhood were slightly higher than those recorded on site, possibly due to the presence of cultural interferences such as power lines. Conductivity values obtained do not indicate the presence of significant bedrock fractures or ground water contamination.

**Proton Precession Magnetometry**

The background magnetic field values recorded during the magnetics survey generally ranged from 55,350 to 55,500 gammas. Small fluctuations in the magnetic field readings may be due to changes in depth to bedrock. Sharp anomalies, greater than 200 gammas above background measurements recorded along line A, are most likely due to the presence of protective steel well casings and piezometers. A similar anomaly along line H is associated with a culvert. The 100 to 150 gamma anomaly on line B may have a geologic source, since the background measurements east of the anomaly are approximately 50 gammas greater than measurements west of the anomaly. In addition, the broad signature

of the anomaly typically represents a geologic feature and not a single metallic object such as a well casing. A similar broad anomaly was measured along line D in the same area.

## 2.3    SOIL GAS SURVEY

A soil gas survey was conducted by Balsam on November 4, 7, 8, and 9, 1988. The objective of the survey was to further characterize the lateral extent of subsurface VOC contamination at the site. Specific objectives included assessing the extent of residual subsurface VOC contamination in the former disposal area, investigating upgradient areas surrounding the piggery building, and identifying potential pathways of contaminated ground water from the former disposal area to the northeast and east to Brook A. Soil gas samples were collected and analyzed from 43 of 60 proposed locations. Seventeen locations could not be sampled due to the presence of shallow bedrock or saturated shallow soil conditions. Subsequently, twenty shallow ground water grab samples were collected on November 30, 1988 and the headspace of these samples was screened for VOCs to supplement soil gas data.

### 2.3.1    Field Techniques

Soil gas samples were collected by driving a 5-foot long, 3/8-inch-diameter, solid steel probe into the ground to a maximum depth of 4 feet or refusal, whichever occurred first. At many locations, the probe could not be driven to 4 feet due to obstructions such as cobbles, boulders or bedrock. A soil gas sample was collected at a location if the probe could be pushed or pounded at least 2 feet into the ground. Generally, the deeper a probe can be pounded into the ground, the less surface conditions or variables such as vegetation, rainfall, temperature and wind will influence the nature of a soil gas sample. After being driven, the probe was removed and a 1/4-inch outside-diameter (OD) stainless steel tube was inserted in

the open hole. Topsoil was then packed around the tube to minimize the flow of ambient air into the hole. At some locations, a rubber gasket was used to seal the probe hole.

Locations where soil gas samples were collected are shown on Figure 2-6. At many locations along the swale and Brook A, bedrock or the water table were shallow, preventing the collection of a soil gas sample at locations where sampling had been planned. These locations are also indicated on Figure 2-6.

Soil gas samples were collected in either a 250-microliter (ul) gas-tight syringe or a 1.5 liter tedlar bag, depending primarily upon the proximity of the sampling location to the location of the analytical support van containing the Photovac gas chromatograph (GC). The first sampling technique involved connecting a tygon tube to the stainless steel tube and withdrawing soil gas with a Gillian air sampling pump, calibrated to a flow rate of approximately one liter per minute. Prior to sample collection, soil gas was withdrawn from the probe hole being sampled for approximately 30 seconds to purge the probe hole of ambient air. The sample was then collected by inserting the gas-tight syringe needle into the tygon tubing at the top of the stainless tube and withdrawing a 250-ul sample with the syringe while soil gas was being withdrawn by the pump. The syringe containing the sample was then transported to the analytical support van and the sample was directly injected into the Photovac GC for analysis. Collection of samples using this technique limited soil gas contact to the stainless steel tube and the syringe.

The second technique employed during the soil gas sampling program entailed collection of soil gas samples in a tedlar bag. This was accomplished by placing a tedlar bag in an airtight container and connecting the tedlar bag with teflon tubing to the stainless steel sampling tube installed in the probe hole. A Gillian air sampling pump was connected to the air-tight container and, after being started, a vacuum was created by the air pump in the air-tight container which, in turn, drew soil gas into the tedlar bag. Once the bag was partially filled, the

pump was turned off and the bag was sealed and removed from the airtight container and delivered to the analytical support van. A 250-ul sample was extracted from the tedlar bag with a gas-tight syringe and injected into the Photovac GC for analysis.

To minimize the risk of cross-contamination between sampling stations, solid steel probe bars were decontaminated between use by rinsing with a solution of trisodium phosphate (TSP) and distilled water followed by a distilled water rinse. Additionally, at each soil gas sampling station, new, pre-cleaned, stainless steel tubing was used.

In order to supplement soil gas data in areas where soil gas samples could not be obtained due to the shallow water table, shallow ground water samples were collected from twenty locations on November 30, 1988. These locations were primarily along Brook A and the swale, as shown on Figure 2-6. These samples are designated by the prefix "HW" for "headspace water" followed by the sample number. The samples were collected by digging a 1-foot deep hole with a shovel, allowing the hole to fill with water, and then collecting a water sample in a 40-milliliter (ml) glass vial equipped with a teflon-lined rubber septa and cap. Ground water samples were placed on ice in a cooler following collection and transported off site to Balsam for analysis by the Photovac GC.

## 2.3.2    Sample Analyses

Soil gas samples were analyzed by Balsam using a Photovac 10S50 GC which was operated on site in a heated van. The shallow ground water grab samples were transported to the Photovac GC at an off-site location. The Photovac employed for the sample analyses utilizes a PID and is equipped with a temperature-controlled capillary chromatographic column. The column employed for these analyses was a CP Sil-1-5. A one-meter pre-column and a nine-meter analytical column were connected in series to achieve separation of sample components.

Soil gas survey analytical data are provided in Appendix C-1 and sample results are presented in the order analyzed. During the four day soil gas survey, the Photovac GC was set up on site in a heated analytical support van so that soil gas samples could be analyzed rapidly after collection and results could be used to assist in directing the soil gas survey program. A generator was used to provide electricity for heating the van and powering the Photovac GC. The Photovac GC was equipped with an isothermal oven powered by a rechargeable 12-volt battery pack.

Prior to beginning the soil gas survey, a library of VOCs of interest was loaded into the memory of the Photovac GC computer. The library contained the following compounds which were selected based upon review of analyses of environmental samples previously collected at the site and discussions with EPA and NHDES:

o    Acetone

o    Benzene

o    1,2-trans-dichloroethylene (1,2-trans-1,2-DCE)

o    Ethylbenzene

o    Tetrachloroethylene (PCE)

o    Tetrahydrofuran (THF)

o    Toluene

o    1,1,1-trichloroethane (TCA)

o    Methyl Ethyl Ketone (MEK)

o    Methyl Isobutyl Ketone (MIBK)

o    Trichloroethylene (TCE) *

*    TCE was added to the computer library prior to beginning the second day of soil gas sampling and analyses.

For the analysis of the ground water grab samples, three additional compounds were included in the library: 1,1-dichloroethylene (1,2-DCE), meta-xylene, and ortho-xylene.

Standards were prepared by injecting a known volume of the pure, gaseous compound into a three-liter tedlar bag which had been filled with ultra zero grade ambient monitoring air. The concentration of the standard in the bag was calculated by the follow equation:

$$C = (v/V)(Pv/760)$$

Where:  C  =  Concentration of standard in the bag, in parts per million (ppm)

v  =  Volume of gaseous standard injected into the bag, in microliters (ul)

V  =  Volume of the tedlar bag, in liters (l)

Pv  =  Vapor pressure of the standard compound at ambient temperature (mm Hg)

760 =  Atmospheric pressure at sea level (mm Hg)

Components of a field sample which were detected by the instrument were compared to the standard compounds within the Photovac GC computer for identification and quantification. Sample components which had a retention time within 10 percent of one of the standard compound retention times were identified as that standard compound by the instrument. However, it is possible that compounds other than the standard compound which eluted within the 10 percent window were identified as the standard compound. Furthermore, the probability that a detected compound could be misidentified as a standard compound in the Photovac library increased as the elution times increased because the window time used for compound identification also increased proportionally. Nevertheless, analyses are typically conducted using the 10 percent window to allow for some

variability in the retention time of late eluting peaks. In cases where the absolute value of the window becomes large due to a compound with a relatively long retention time, the Photovac operator evaluated whether the retention time of an identified compound appearing within the 10 percent window varies significantly enough from the library retention time to be considered a misidentification.

Each day prior to beginning analysis of the soil gas or ground water headspace samples, an analytical standard was prepared by the method described above for the library standards that consisted of three of the compounds contained in the library. This standard mixture was analyzed one to two times per day as a method of monitoring the response of the instrument to these compounds as compared to the response programmed into the Photovac GC library for these same compounds. In addition, the standard mixture was used to monitor shifts in standard retention times which might have been caused by variations of the operating environment or instrument conditions. For instance, as the battery pack that powers the isothermal oven discharges, the oven and column will begin to operate at a somewhat lower temperature and the retention times for components passing through or eluting from the column will increase proportionally.

Soil gas samples were collected and analyzed on November 4, 7, 8, and 9, 1988. Samples received in a 250-ul syringe were injected directly into the instrument, and samples collected in tedlar bags were withdrawn from the bags with a 250-ul gas-tight syringe through a rubber-capped fill adapter. Each soil gas sample was analyzed within one-half hour of collection; most were analyzed within ten minutes of collection.

In addition to soil gas samples analyzed during this phase of the investigation, shallow ground water grab samples were also analyzed on the Photovac GC. These samples were received on November 30, 1988 and analyzed on December 1 and 2, 1988. Prior to analysis, samples were allowed to equilibrate to room temperature, a headspace was created by withdrawing 15 ml of water from each vial with a syringe, and the samples were shaken vigorously. Samples were then

allowed to equilibrate for five minutes, after which a headspace sample was withdrawn with a gas-tight syringe and directly injected into the Photovac GC.

To provide internal quality control/quality assurance (QA/QC) during analysis of the soil gas and ground water headspace samples, syringe blank and replicate sample analyses were performed at appropriate intervals in accordance with the Photovac GC Standard Operating Procedures contained in the Mottolo site Project Operations Plan (POP) (Balsam, 1988). Twenty-three syringe blank sample analyses, three replicate sample analyses, one apparatus blank sample analysis, and one carrier gas blank sample analysis were performed during soil gas analyses. During analysis of the ground water headspace samples, nine syringe blank sample analyses and three replicate sample analyses were performed as QA/QC measures. Also, as previously discussed, analysis of a three-component standard mixture was also performed daily as a QA/QC measure during the soil gas and ground water headspace analyses.

During analyses of the soil gas samples, acetone and ethylbenzene were identified in many of the syringe blank sample analyses, generally at levels between 100 and 200 parts per billion (ppb). As a result, analyses in which acetone and/or ethylbenzene were reported present at concentrations similar to those found in the associated syringe blank samples were qualified as possibly containing extraneous VOCs not related to site contamination based upon the evaluation of the data by the chemist who performed the analyses. This evaluation included reviewing the soil gas sample results in the order analyzed (as presented in Appendix C-1) with respect to the previous and following blank sample results. These qualifications are noted where appropriate on Tables 2-3 and 2-4, which present a summary of the soil gas survey and ground water headspace analytical results. This qualification was considered in evaluating the significance of these soil gas analytical findings. Many of the soil gas samples did exhibit a small early eluting peak which was identified as acetone; blank sample contamination identified as acetone was also observed during a portion of the soil gas sample analyses. Because acetone was nearly absent from soil and water samples collected from the

site and analyzed by an analytical laboratory employing a much more vigorous technique, the presence of this early eluting peak is principally attributable to extraneous sample contamination. With respect to the reported presence of ethylbenzene in soil gas samples, this VOC was also observed in syringe blank samples. However, unlike acetone, significant levels of ethylbenzene were found in site soil and ground water samples analyzed by a contract laboratory. As such, this VOC cannot be fully attributed to extraneous sample contamination. Rather, the result should be considered as an indicator of the possible presence of this VOC, while recognizing that the reported presence may be attributed to extraneous contamination introduced during sample analysis. During headspace analysis of ground water samples, syringe blank contamination was not encountered.

For both the soil gas and ground water headspace samples, chromatographic peaks that could not be correlated with the standard library compounds were labeled as "unknown" by the computer. The number of unknown peaks detected are reported in Tables 2-3 and 2-4. The identities and concentration levels of these unknown peaks cannot be reliably estimated due to the varying response of the Photovac GC to various VOCs.

### 2.3.3    Data Interpretation

The study area was divided into several areas of interest to facilitate data interpretation. These are shown on Figure 2-7 and include:

A. The former disposal area,

B. Upgradient of the former disposal area, including the piggery building and concrete pad,

C. The piggery solid waste pile area southeast of the piggery building,

D. The former drum staging area north of the swale,

E. The swale drainage area due north of the piggery building,

F. The northeast lowland area west of Brook A, and

G. Lowlands east of Brook A.

Soil gas sampling was conducted in each of these areas; whereas, the shallow ground water grab sampling was focused to evaluate areas with a predominance of saturated soil conditions, i.e., the swale drainage area and lowlands adjacent to Brook A.

Analytical results of soil gas and shallow ground water headspace samples are summarized in Tables 2-3 and 2-4, respectively. A detailed log of sample analyses is provided in Appendix C-1. Total concentrations of the indicator VOCs detected at each sampling location are shown on Figure 2-7. As noted earlier, syringe contamination may be the source of a significant percentage of the acetone, and to some extent, ethylbenzene reported present in some of the soil gas samples.

The soil gas survey confirmed the presence of VOC contamination in the former disposal area (Area A) where concentrations of total VOCs were detected ranging from 0.33 to 500 ppm in soil gas samples from several locations in this area. The headspace of the shallow ground water sample HW-119 collected from the approximate location of the original swale, and a former run-off containment pond, contained over 50 ppm of total VOCs. Indicator compounds were also detected in samples from some areas adjacent to the former disposal area but at concentrations less than 0.5 ppm.

In the upgradient area surrounding the piggery building (Area B), VOCs were detected in soil gas samples at concentrations between 0.1 and 0.4 ppm. Compounds detected included acetone and ethylbenzene, which were also detected in several syringe blank samples. Based on the relatively low concentration of VOCs detected in soil gas, it is unlikely that large areas of soil containing VOCs are present within this area.

Soil gas sample X-14 and the headspace ground water sample HW-101, obtained from a seep which emanates from the toe of the piggery solid waste pile (Area C), contained no detectable levels of indicator compounds. These data are consistent with earlier state and federal regulatory agency findings that this is not an area of significant VOC contamination.

Soil gas samples could not be obtained in the area of the drainage swale (Area E) due to saturated ground conditions. Instead, several shallow ground water grab samples were obtained. Upgradient, adjacent to the swale, no indicator VOCs were identified in headspaces of samples from locations HW-116 and HW-118. The headspace of the ground water sample from location HW-117, located just northwest of the former disposal area and south of the swale, contained 0.08 ppm of acetone, 0.04 ppm of ethylbenzene, and 0.05 ppm of 1,2-DCE. The first two compounds may be attributed to analytical system contamination, but the last compound may represent the northwesterly extent of shallow VOC contamination related to the former disposal area. In the headspace of a sample of the swale water collected at location HW-115, 0.04 ppm of 1,2-DCE and 0.15 ppm of TCE were detected. Further downgradient along the swale, just west of Brook A, 0.35 ppm of toluene was detected in the sample headspace from location HW-103, and 0.2 ppm of 1,2-DCE and 0.2 ppm of 1,2-DCE were detected in the sample headspace from location HW-102, just south of the swale along Brook A.

North of the swale in the former drum staging area (Area D), 0.72 ppm of acetone was detected in soil gas collected at location G-12 and 0.35 ppm of THF was detected in soil gas collected at location X-1. Since there is no record of disposal activities in this area, the source of these compounds may be residual localized contamination in the overburden resulting from staging operations during the removal action conducted by EPA from 1980 through 1981 or past site activities in this area.

In the lowland area northeast of the former disposal area (Area F), VOCs were detected in both soil gas and the headspace of shallow ground water samples

(HW-112, HW-113, X-2, X-3, X-5, and X-11). The VOCs observed differed in nature and concentration at each location, but their existence in this area may indicate a component of contaminant transport in shallow ground water to the northeast toward Brook A. However, indicator VOCs were not detected in five shallow ground water samples in this area adjacent to Brook A. East of Brook A, indicator VOCs were not detected in samples except for 0.1 ppm of ethylbenzene at location X-10; as previously stated, this VOC could be attributed to extraneous sample contamination.

In general, the objectives of the soil gas survey were met and several generalized conclusions were drawn based upon the findings reported. The most significant subsurface VOC contamination appears to be located in the former disposal area and in a localized zone extending along the drainage swale from the disposal area to Brook A. Levels of VOCs which indicated the presence of contamination related to disposal activities were not detected immediately upgradient of the disposal area, immediately downgradient of the piggery solid waste pile, or east of Brook A. Some low levels of residual VOC contamination may exist in the former drum staging area north of the swale, possibly associated with drum staging operations conducted in this area. Low concentrations of indicator VOCs detected in samples from the northeast lowland area west of Brook A indicate that a northeasterly component of overburden or shallow bedrock ground water flow is possible. Since new areas of prominent subsurface contamination were not identified at this stage of the RI, proposed locations of monitoring wells were not changed. Soil gas data were used in the subsequent soils investigation to determine the locations of several borings in the former disposal area. These data were used in conjunction with other RI data in Section 4.0, where the nature and extent of contamination is discussed.

## 2.4     SOIL INVESTIGATIONS

Soil investigations were conducted during the RI to describe the lateral and vertical extent of contaminated soil and soil characteristics.  These investigations consisted of a three-phase soil boring program discussed below.

### 2.4.1     Soil Boring Programs

Phase I of the soil boring program was conducted to provide data to assess the types of contaminants present in soil within the former disposal area.  The Phase I program included the completion of four soil borings, BE-1 through BE-4, on November 8, 1988 and November 9, 1988.  One soil sample from each of three borings was analyzed for THF, methyl t-butyl ether (MTBE), full Hazardous Substance List (HSL) parameters, and total volatile solids (TVS); a sample was not submitted from the fourth boring due to the shallow depth of the boring.

Based upon the findings of the Phase I program and the soil gas sampling program, a Phase II program was developed.  Phase II was conducted to further describe the vertical and horizontal extent of contaminated soil in the former disposal area, the former drum staging/sampling area north of the swale and portions of the site which may have been affected by VOCs migrating from these areas.  The Phase II program included the completion of sixteen soil borings, BE-5 through BE-20, between December 27, 1988 and January 13, 1989.  Analytes in the Phase II program included THF, MTBE, HSL VOCs, lead, and TVS.

The Phase III program included the completion of five soil borings, BE-21 through BE-25, around the larger concrete pad on September 19, 1989.  Phase III was conducted based upon previous ground water analytical results indicating a potential VOC source area located in the upland portion of the site, west of the main piggery building, and unrelated to the former disposal area.  The objective of this program was to identify a VOC source area near the concrete pad.  Based upon results of field screening data which did not indicate the presence of elevated

levels of VOCs, soil samples were not submitted for laboratory analysis from this program.

**Field Procedures**

Borings were advanced using 3 1/4-inch and 4 1/4-inch inside-diameter (ID) hollow-stem auger drilling procedures until split-spoon and auger refusal were encountered. Phase I and Phase II borings were advanced by Soil Exploration Corporation of Leominster, Massachusetts using a Mobile B-53 tire-mounted all-terrain drilling rig. Phase III borings were advanced by Avalanche Soil Exploration, Inc. of Gorham, Maine using a Mobile B-47 track-mounted drilling rig. Continuous soil sampling was performed in 2-foot increments using either a 2-inch or 1 3/8-inch ID split-spoon sampler. Soil characteristics were logged by Balsam personnel using the Burmister classification system. Boring locations are shown on Figure 2-8. Boring logs are provided as Appendix B-3.

Three soil borings, BE-1 through BE-3, were originally proposed for Phase I. Borings were located within the former disposal area as defined by an aerial photograph review, a site reconnaissance, and available data. Boring BE-4 was added due to the shallow depth to refusal encountered at boring location BE-1.

Fifteen soil borings, BE-5 through BE-19, were originally proposed for Phase II. Borings were located within and around the perimeter of the estimated extent of the former disposal area, adjacent to the site drainage swale, adjacent to a former surface water collection and infiltration basin constructed during the EPA removal action, and upgradient of the former disposal area to identify the lateral and vertical extent of soil contamination and background soil quality. Three soil borings were also completed in the former drum staging area north of the swale to assess residual soil contamination which may have resulted from drum staging/sampling activities during 1980 and 1981. An additional boring, BE-20, was added to the program during the course of Phase II field activities to better delineate the lateral extent of soil contamination.

During Phase II, several attempts were required to complete a boring at most locations due to difficulty in advancing augers or split-spoon samplers because of the presence of cobbles and boulders in subsurface materials. In some cases, an additional boring or borings were completed adjacent to the first location to confirm that auger and split-spoon refusal was likely at bedrock. Multiple locations are shown on Figure 2-8. Boreholes were filled to the ground surface with cement-bentonite grout or hydrated bentonite upon completion.

During Phase III, five soil borings, BE-21 through BE-25, were advanced around the perimeter of the large concrete pad west of the piggery building in the upland portion of the site, as shown on Figure 2-8. These borings were also advanced until split-spoon and auger refusal were encountered and were filled with grout to the ground surface upon completion.

A summary of soil boring depths and the approximate depths at which ground water was encountered are provided in Table 2-5. Phase I and Phase II boring locations were established by a survey on January 30 and 31, 1989, and Phase III boring locations were established by a survey on March 9, 1990.

**Sampling Procedures**

Samples collected during the boring programs were obtained in general accordance with the Standard Penetration Test Method, ASTM D1586, which specifies soil sample collection using a split-spoon sampler driven by a 140-pound hammer falling 30 inches. At least 2 feet of penetration was attempted at each sampling interval; however, penetration and recovery were often less than 2 feet due to obstructions and soil type. At sampling intervals selected for splitting of samples with EPA, the split-spoon sampler was overdriven by 0.5 feet to improve the likelihood of obtaining sufficient recovery for both Balsam and EPA sample testing requirements.

Upon retrieval from the borehole, the split-spoon sampler was opened on a clean, plastic sheet. The contents were immediately screened in the split-spoon, weather conditions permitting, with an HNu PID (HNu) or a Foxboro Organic Vapor Analyzer 128 (OVA) to provide an initial indication of whether the sample contained VOCs. Soil was then collected with a stainless steel spatula from multiple locations within the split-spoon sampler in an effort to obtain samples representative of the sampling interval. Containers for analytical samples were labeled prior to or just after sample collection with the following information: Balsam project number, sample number, date, and time of collection. Additional glass jars, labeled with appropriate boring-specific information, were filled with some of the soil remaining in the split-spoon to allow for VOC field screening and further soil sample assessment at a future time.

Phase I soil samples were collected in the following pre-cleaned containers supplied by the analytical laboratory: one 40-ml glass vial with teflon septum (VOCs), one 8-ounce glass jar (HSL semi-volatile organic substances and pesticides/PCBs), and one 120-ml plastic container (HSL inorganic compounds, cyanide, and TVS). An additional 4-ounce or 8-ounce glass jar was filled half way, capped with aluminum foil, and covered for subsequent field screening for VOCs using an HNu.

Phase II soil samples were collected in the following pre-cleaned containers supplied by the analytical laboratory: one 40-ml glass vial (VOCs) and one 120-ml plastic container (lead and TVS). In addition, a 40-ml glass vial with teflon septum was filled with soil from the 0 to 6-inch interval and from each subsequent sampling interval at each boring location. One 4-ounce or 8-ounce glass jar was also filled half way, capped with aluminum foil and covered.

Phase II soil samples in 40-ml glass vials were also subjected to analyses by Balsam with a Photovac GC; samples collected in 4-ounce or 8-ounce glass jars were screened in the field for VOCs with an OVA or HNu. The Photovac GC VOC analyses were performed to provide additional compound-specific data on soil

quality. For VOC field screening, the soil samples contained in 4-ounce or 8-ounce glass jars were typically brought to the heated on-site field van, allowed to warm for at least ten minutes, and the headspace was then screened for VOCs by inserting the HNu or OVA probe through the foil cover. HNu or OVA screening results are presented on the boring logs in Appendix B-3. A discussion of Photovac GC and field screening data is provided in Section 2.4.3.

During the Phase II program, split samples were collected for EPA by Balsam personnel at boring locations BE-6, BE-10, BE-13, and BE-19. Split sample containers were provided by EPA personnel.

Phase III samples were screened in the field with an HNu or OVA using procedures similar to those described above for Phase II. Screening results are provided on boring logs in Appendix B-3.

Samples were stored on ice in coolers immediately after sample collection and were kept on ice during shipment to the analytical laboratory or while awaiting in-house headspace screening analysis, with the exception of samples collected for on-site screening of VOCs using an HNu or OVA and samples collected for future physical characterization. Chain-of-custody records were maintained throughout the boring programs.

The split-spoon sampler and sample collection spatula were decontaminated before each use by scrubbing with a TSP and water solution, followed by a potable water rinse to minimize potential cross-contamination. Decontamination of gloves worn by sampling team members was also conducted in a similar manner before each sample was collected. Drilling equipment used in the borehole, including augers, rods and plugs, was decontaminated by steam cleaning prior to use at each boring location. The steam cleaning was conducted over a steel tub located on the site decontamination pad. The concrete pad located west of the piggery building was used as the decontamination pad. Decontamination water was screened periodically with an HNu or OVA and allowed to recharge in the vicinity of the

decontamination pad, if field screening results were less than the 10 ppm action level requiring containment as specified in the POP. Containerization of decontamination water was not required during the soil boring programs.

Soil cuttings, decontamination water generated at the drilling rig, and excess soil from the split-spoon samplers were allowed to remain on site without containerization if field screening results met the criterion of less than 10 ppm total VOCs as specified in the POP. This criterion was exceeded for soil cuttings and excess soil from the split-spoon samplers at borings BE-9 and BE-10. Cuttings and excess soil from these borings were containerized on site in a 55-gallon drum which was sealed, labeled, and placed in an on-site trailer where they remained.

**Sample Selection Rationale**

The objective of the Phase I sampling program was to obtain the most highly contaminated samples from boring locations within the former disposal area. Laboratory analytical results from Phase I could then be used to focus analytical requirements for the Phase II program. Selection of samples to be submitted for analyses during the Phase I program was based primarily on the results of field VOC headspace screening, though soil characteristics including soil type, staining, presence of foreign material, and degree of saturation were also considered. The soil sample from each Phase I boring with the highest VOC field screening response was submitted for full HSL analyses with the exception of boring BE-1 from which no sample was submitted due to the shallow depth of the boring.

Soil samples submitted for laboratory analyses during the Phase II program were selected to represent soil quality upgradient and downgradient of the former disposal area, above and below the water table, in the former drum staging/sampling area north of the swale, and around the perimeter of the former disposal area.

## 2.4.2    Analytical Summary

One hundred and sixteen soil samples were collected during the three boring programs and screened in the field for VOCs. A total of nineteen of these samples from Phases I and II were submitted for analysis of selected HSL compounds and other specified parameters. A summary of samples submitted for analyses and the specific analyses performed is provided in Table 2-6.

Samples collected during the Phase I boring program were analyzed for full HSL organic compounds, THF, MTBE, HSL Pesticides/PCBs, HSL inorganic compounds including cyanide, and TVS. These analyses were performed to provide data to identify the types of contamination within the former disposal area. TVS analyses were conducted to provide data for use in assessing contaminant migration and various remedial actions as part of the FS.

Reduced analytical criteria were developed in conjunction with EPA and NHDES for the Phase II boring program based upon results of the soil gas survey and the Phase I boring program soil sample analytical data. The refined suite of analyses consisted of THF, MTBE, HSL VOCs, lead, and TVS. VOC analysis was selected because VOCs were deemed the most prevalent type of contaminants present on site. Lead analysis was selected because lead was identified in one of the Phase I soil samples (BE-4) at a concentration above that generally expected to occur in soils in the study area. TVS analyses were selected for similar reasons as those discussed for Phase I.

Summary listings of the compounds detected in soils collected during the Phase I and Phase II programs are provided in Table 2-7 and Table 2-8, respectively. Phase I and Phase II TVS results are provided in Table 2-9. Results of these analyses are discussed in Section 2.4.5. Summary data sheets and associated validated data summaries for Phase I and II analytical parameters are provided in Appendix C-2. Complete CLP data packages have previously been submitted to the EPA under separate cover.

Soil sample headspace of 82 samples was analyzed in-house by Balsam using a Photovac GC. Based on prior data, the Photovac library was programmed to identify fourteen target compounds listed below:

o   acetone
o   benzene
o   trans-1,2-DCE
o   THF
o   toluene
o   TCE
o   MEK
o   MIBK
o   TCA
o   ethylbenzene
o   meta-xylene
o   ortho-xylene
o   PCE
o   1,2-DCE

Results of Photovac GC analyses are provided in Appendix C-6 and are discussed in Section 2.4.5.

During Phase II, four quality control samples were submitted for analysis of VOCs. On three occasions, aqueous trip blank samples were stored with the samples collected and submitted to the analytical laboratory with the soil samples selected for analysis. One field method blank sample was also obtained and submitted to the analytical laboratory for VOC analyses. The field blank sample was collected by pouring an aqueous blank sample provided by the laboratory over a decontaminated split-spoon sampler and collecting the water in two 40-ml glass vials. Analytical parameters requested are provided in Table 2-6. Results of the QA/QC sample analyses are provided in Appendix C-2.

## 2.4.3    Soil Sample Screening Data Summary

During the boring programs, soil samples were screened for VOCs in the field using an HNu or OVA, as discussed previously. During the Phase II program, an additional soil sample was collected from each sampling interval and screened for VOCs using a Photovac GC. HNu, OVA, and Photovac GC screening were performed to provide additional data on soil quality for samples not submitted for CLP analysis.

HNu and OVA results generally were comparable to CLP data within the detection limits of field screening instrumentation. Results suggest that HNu and OVA responses generally served as good indicators of VOC-affected soils, though some screening data did not correlate directly with laboratory analytical results.

The photovac GC was used to screen soil samples obtained during the Phase II boring program for VOCs. Duplicates of 16 of these samples were also submitted to the analytical laboratory for VOC analysis. A comparison of the data from these duplicate analyses indicates that, in those samples where target compounds were not detected or were detected at very low levels by Photovac GC analysis, target compounds were not detected or were detected at very low levels by laboratory analysis. Furthermore, Photovac GC results that indicated elevated VOC concentrations generally correspond to elevated concentrations reported by the analytical laboratory. There were a few cases where compounds and the relative concentrations reported in laboratory samples were not indicated by Photovac GC results. Sufficient numbers of soil samples with elevated VOC levels were not analyzed to allow a complete evaluation of the correlation between Photovac GC and laboratory analyses compound identification.

General trends that can be observed from reviewing the HNu, OVA, Photovac GC, and laboratory analytical data include:

1. Very low and not detected results reported by the screening methods were generally confirmed by CLP analysis and, accordingly, appear to accurately reflect the absence or presence of low levels of VOCs in soil samples.

2. Concentrations of VOCs detected and reported by the screening methods are generally higher than those reported by CLP analysis due possibly in part to the preference of the VOC for the vapor (headspace) phase. Accordingly, screening results appear to be more sensitive indicators for the presence of VOCs in site soils.

Based upon a review of the data discussed above, the VOC headspace screening results correlate well with laboratory results. The VOC screening results for soil samples that were not submitted for laboratory analysis therefore appear to be useful for describing the degree and extent of soil contamination. The nature and extent of soil contamination is discussed further in Section 4.0.

### 2.4.4    Data Validation

Validation of the Phase I and Phase II data reported by the analytical laboratory was performed by Balsam using criteria established in the following documents: the Mottolo POP; "Laboratory Data Validation, Functional Guidelines for Evaluating Organics Analyses," dated February 1988, EPA; and "Laboratory Data Validation, Functional Guidelines for Evaluating Inorganics Analyses," dated July 1988, EPA. Parameters evaluated in data validation for organic compound analyses included:

o   integrity and completeness of the data package,
o   holding times,
o   GC/MS tuning,
o   initial and continuing calibration,
o   blank samples,

o   surrogate recoveries,

o   matrix recoveries,

o   internal standard performance,

o   compound identification,

o   compound quantitation and reported detection limits, and

o   tentatively identified compounds.

Parameters evaluated in the data validation for inorganic compound analyses included:

o   integrity and completeness of the data package,

o   holding times,

o   initial and continuing calibrations,

o   laboratory blank samples,

o   ICP interference check samples,

o   laboratory control samples,

o   duplicate sample analysis,

o   matrix spike samples,

o   furnace atomic absorption quality control, and

o   ICP serial dilution.

Validation indicated that the data met the Data Quality Objectives (DQOs) set forth in the POP and the Scoping of Response Actions Phase I report (Balsam, 1988). Analytical results for QA/QC samples are included in Appendix C-2.

## 2.4.5    Data Presentation

Review of boring logs generated from the boring program indicates that fine to medium and fine to coarse sands are the predominant sediments in the areas investigated. However, the lesser soil fraction varies significantly in type and stratigraphy, ranging from silty sands to gravels. This heterogeneity and varying

stratigraphy may be due to remedial activities and/or filling operations conducted previously at the site. General stratigraphy consists of fine to medium or fine to coarse sands, underlain in areas by a poorly-sorted glacial till.

Phase I and Phase II laboratory results indicate that the primary VOCs identified in on-site soils were methylene chloride, toluene, ethylbenzene, and xylene. At borings located within and near the toe of the former disposal area, chlorinated and non-chlorinated VOCs including acetone, TCA, TCE, and PCE were also identified in site soils. In addition, lead was identified at concentrations somewhat above those generally expected in study area soils in samples obtained from borings BE-4, BE-9, BE-10, and BE-16, located within and just north of the former disposal area. Results indicate that most VOCs were identified from soil samples collected just above or at the water table during boring advancement. Based upon field screening data collected during Phase III activities, prominent soil contamination was not identified in soil samples collected adjacent to the large concrete pad. Further interpretation of these data is provided in Section 4.0.

## 2.5 GROUND WATER INVESTIGATIONS

### 2.5.1 Monitoring Well Installation Program

The monitoring well installation program was conducted to collect data regarding formation characteristics, hydraulic conditions, and ground water quality. This program consisted of the installation of 30 monitoring wells by Soil Exploration Corporation of Leominster, MA and Gap Mountain Drilling of Fitzwilliam, New Hampshire. These wells were installed during the period extending from November 9, 1988 to January 19, 1989. Four additional monitoring wells were installed at the site from September 25, 1989 to September 28, 1989 by Avalanche Soil Exploration, Inc. of Gorham, Maine.

Twenty-five of the 34 wells were installed at new locations and were typically completed in clusters of two, consisting of one overburden well and one shallow or

deep bedrock well. At some locations, the overburden was too thin to install a monitoring well or ground water was not encountered in the overburden; in such cases, only a bedrock well was installed. The remaining nine wells were constructed to replace previously installed wells that Balsam deemed to have been constructed insufficiently to serve as reliable ground water monitoring wells. However, the wells being replaced were not abandoned in order to allow their use for ground water elevation measurements.

Of the total of 34 wells, 26 were installed within the site area (Mottolo property) and eight were installed off site, within the study area. Table 2-10 summarizes these well installations with regard to well designation, location, installation technique, and stratigraphic unit of completion. Figures 2-9 and 2-10 show the well locations within the site and study areas, respectively, including wells installed during previous investigations. Table 2-11 provides well construction data for the 34 wells discussed above and for the wells installed as part of previous investigations. Figure 2-11 illustrates the typical designs of the well installations completed during the RI.

Following completion of the monitoring well installation program, well locations and elevations were surveyed and added to the study area base map.

**General Field Procedures**

Borings for the monitoring wells were advanced using tire-mounted or track-mounted Mobile B-47 and Mobile B-53 drill rigs, or a Reichdrill T-650-W air-rotary drill rig. Boreholes were advanced using either 4 1/4 or 6 1/2-inch ID hollow-stem augers, NX (2 7/8-inch outside diameter (OD) or HQ (3 7/8-inch OD) core barrels, 5 5/8-inch or 10-inch tri-cone roller bits, a 5 7/8-inch OD air hammer, or 4 1/4 inch OD ODEX air hammer. In order to construct some of the bedrock monitoring wells, casing was spun or the borehole was reamed out with a tri-cone roller bit approximately one-half to 1-foot into bedrock at the overburden interface.

Several combinations of the drilling equipment and techniques described above were used to achieve the objectives of the monitoring well installation program while providing adequately constructed monitoring wells. The actual techniques used to complete each well are summarized on the well completion logs contained in Appendix B-3.

Potable water obtained from the Raymond Fire Department was the drilling fluid typically used during the monitoring well installation program. Some drilling mud was used during the installation of casing in the overburden for two bedrock wells (MW-7D and MW-18D) and some vegetable oil was poured directly down the drill stem to lubricate the bit of the air rotary rig during the installation of the deep off-site bedrock wells. During the course of well installation, drilling fluids used were screened with an HNu or OVA for the presence of VOCs. At on-site locations where headspace analyses of the drilling fluids for VOCs exceeded 10 ppm, the fluids were placed into 55-gallon drums and left on site at the well locations as specified in the POP. Drilling fluids generated during the installation of off-site wells did not produce VOCs at levels greater than the established off-site action level of 2 ppm.

Continuous soil sampling was performed, where possible, using 24-inch long, 1 3/8-inch ID split-spoon samplers for borings advanced within the site area. Samples were similarly collected at 5-foot intervals during off-site overburden well installations. Generally, soil samples were collected from one boring if a well cluster was installed, and the adjacent boring was advanced without sampling. Sampling was conducted in general accordance with Standard Penetration Test Method ASTM-D-1586, and penetration, sample recovery, and blow counts were recorded by Balsam personnel on the boring logs. Boring logs were completed using the Burmister soil classification system and are attached as Appendix B-3.

Soil samples collected in the split-spoons were screened in the field using an HNu or OVA. Screening was conducted by filling a glass jar approximately one-half full

with the soil sample, allowing it to equilibrate at room temperature, and inserting the field instrument probe beneath the jar lid into the headspace. Screening results are shown on the boring logs.

Auger cuttings were also screened periodically during boring advancement and at completion of the borehole using an HNu or OVA. Auger cuttings from on-site borings that produced VOC levels exceeding 10 ppm were placed into 55-gallon drums and stored in a trailer on site where they remained. Auger cuttings from borings advanced at the off-site locations within the study area did not produce VOC levels that exceeded the established off-site action level of 2 ppm.

Upon completion of the monitoring well installation program, selected soil samples were retained by Balsam for subsequent physical testing of selected samples (see Section 2.5.2).

Rock cores were collected at shallow bedrock well locations using standard rock coring techniques and equipment (i.e., NX core barrels or a double tube HQ core barrel). Core runs were generally completed in 5-foot lengths and bedrock was cored for the installation of each new and replacement shallow bedrock well excluding wells MW-8D and MW-7D, where boreholes were advanced using air rotary techniques. A Balsam geologist recorded rock quality designation (RQD), percent core recovery, drilling rates, rock type, description of rock material, rock fracturing, weathering, and pertinent rock defects. Rock coring logs are included in Appendix B-3.

Composite samples of rock chips were collected over run lengths ranging from two to 10 feet during the installation of deep bedrock wells installed off site and from the two bedrock wells installed on site by air hammer methods. Rock chips blown from the borehole were obtained with a strainer over each sampling interval. Samples were then washed, placed in glass jars, and assessed by a Balsam geologist, who recorded drilling rate, rock type, description of rock material, and weathering data. Rock drilling logs are included in Appendix B-3.

Drilling rigs, drilling equipment, soil sampling equipment, and rock coring equipment were decontaminated before and after each use at on-site well locations using TSP and a high-pressure steam cleaner operated on the concrete decontamination pad. Decontamination of the split-spoon samplers was conducted prior to each use and consisted of washing and scrubbing with TSP in potable water, followed by scrubbing and rinsing with potable water. Decontamination water was screened on site with an HNu or OVA in accordance with approved procedures. Headspace screening of the decontamination water did not produce VOC readings at levels greater than background levels at either on-site or off-site drilling locations. Therefore, containerization of decontamination water was not required.

**Overburden Monitoring Wells**

Thirteen overburden monitoring wells were installed during the monitoring well installation program. Eleven wells were installed within the site area and two were installed at off-property locations within the study area. Ten of the thirteen overburden wells were installed at new locations and three wells were installed to replace existing wells.

Hollow-stem auger drilling procedures were generally used to advance borings for the overburden well installations. Potable water was used in limited situations, where necessary, to maintain a pressure head inside the augers and thus limit sand from running inside the augers during well construction. All boreholes, excluding MW-8S, were drilled to a depth where auger and split-spoon refusal were encountered. To confirm that refusal depth represented the bedrock surface, coring was conducted in either the overburden borehole or in the adjacent borehole advanced for the purpose of installing a bedrock well. In overburden monitoring well boreholes where the borehole was advanced to bedrock or where rock coring was performed, the borehole was filled with hydrated bentonite pellets to a minimum depth of approximately one-half foot above the overburden-bedrock interface.

Typically, overburden monitoring wells were constructed using nominal 2-inch-diameter, flush-threaded, Schedule 40 PVC riser pipe and 0.01-inch slotted PVC well screen. A filter pack of silica sand with a grain size of approximately 0.02 inches was placed in the annular space around the well screen, extending from approximately one-half foot beneath the well bottom to a minimum of 1 foot above the well screen. The remainder of the annular space was filled with hydrated bentonite. The wells were secured with 6-foot long, 4-inch-diameter, steel protective casings and locks. Protective casings were generally cemented to a depth of 4 feet below ground surface to minimize the potential for frost heaving.

Overburden monitoring wells installed during the RI ranged in depth from approximately 6 to 27 feet below ground surface.

**Shallow Bedrock Monitoring Wells**

Fifteen shallow bedrock monitoring wells were installed during the monitoring well installation program within the site area. Nine of the wells were installed at new locations and six were installed as replacements wells.

The majority of the shallow bedrock monitoring wells were completed using standard rock coring procedures. Boreholes were typically advanced through the overburden using either 4 1/4-inch or 6 1/2-inch ID hollow-stem augers or an ODEX air hammer. Either NX or double-tube HQ core barrels and potable water were then used to advance the borehole into bedrock. Two of the shallow bedrock wells (MW-7D and MW-8D) were completed using air rotary drilling techniques. For wells MW-7D and MW 8D, the boreholes were advanced through the overburden using a 10-inch-diameter tri-cone roller bit. A 5 7/8-inch-diameter air hammer was then used to advance the borehole into bedrock. During installation of well MW-7D, drilling mud was used while advancing the boring through the overburden to prevent caving.

Shallow bedrock monitoring wells were completed as open holes in the bedrock or, in some cases, a 2-inch-ID, flush-threaded, Schedule 40 PVC riser pipe and 0.10-inch PVC well screen were installed within the corehole. In the open hole wells, a 3-, 4-, or 6-inch-diameter steel casing (dependent upon the corehole diameter) was seated approximately 3 to 5 feet into the bedrock and grouted to ground surface generally using displacement grouting techniques. Displacement grouting involved filling the borehole with a volume of grout sufficient to fill the annular space when a steel casing fitted with a cement plug was lowered into the borehole and seated on bedrock. Grout was mixed on site in a cement-bentonite ratio generally of 6:1 and allowed to set for a minimum of 24 hours after placement before the boring was advanced through the cement plug using conventional rock coring or air hammer drilling techniques, as discussed above. In cases where the bedrock was soft, a 10- or 12-inch-diameter roller bit was advanced approximately one-half to one foot into the bedrock in order to provide additional annular space for the grout seal.

In shallow bedrock wells constructed with PVC, a silica sand filter pack with a grain size of approximately 0.02 inches was installed in the annular space around the well screen, extending from approximately one-half foot beneath the well bottom to a minimum depth of approximately 2 feet above the screened zone. The remainder of the annular space was then filled with hydrated bentonite pellets or a cement-bentonite grout mixed at a ratio of 6:1. Wells were then secured with 5- or 6-foot long, 3- or 4-inch diameter, steel protective casings and locks. Protective casings were generally cemented to a depth of 4 feet below ground surface to minimize the potential for frost heaving. The Rock Drilling Logs and Well Completion Reports provided in Appendix B-3 contain specific drilling and well installation details.

**Deep Bedrock Monitoring Wells**

Six deep bedrock monitoring wells were installed during the monitoring well program at off-site locations within the study area. These monitoring wells were

completed as open holes in bedrock to a depth of approximately 225 feet. The well depth was equal to the average depth of residential wells in the Blueberry Hill development.

Rotary air hammer drilling techniques were used to advance the boreholes for the deep bedrock wells. Boreholes were advanced through the overburden and approximately 10-feet into bedrock using a 10-inch-diameter tri-cone roller bit. During drilling of monitoring well MW-18D, it was necessary to use drilling mud while drilling through the overburden in order to prevent caving.

A 6-inch-diameter steel casing was grouted into the bedrock following advancement of the deep bedrock well borehole in shallow (10 feet) bedrock using a cement-bentonite grout mixed at a ratio of approximately 6:1. Grout was pumped down along the exterior of the casing until the annular space was filled. The grout was allowed to set a minimum of 24 hours before the borehole was advanced with the 5 7/8-inch air hammer to an approximate depth of 225 feet. Deep bedrock wells were secured with 6.5-foot long diameter steel protective casings cemented to a depth of approximately 4 feet beneath ground surface.

**Monitoring Well Development**

Monitoring wells installed during the RI and wells installed during previous investigations that were included in the RI ground water sampling program were developed prior to sampling by Balsam between December 12, 1988 and April 11, 1989.

The objectives of well development included:

o   Removing drilling fluids from the well and adjacent formation, in order to reduce effects of the fluids on water quality in subsequent ground water sampling events,

o  Improving the permeability of the filter pack and formation around the well
   screen by removing fine-grained particles so ground water would flow freely
   into the well,

o  Allowing for the collection of more sediment-free ground water samples,

o  Providing information on well yield to assist in the organization of subsequent
   ground water sampling rounds.

Specific well development details are provided in the well completion reports in
Appendix B-3. Dates that wells were developed are summarized on these well
completion reports and in the monitoring well construction summary data provided
in Table 2-11. Wells were developed by either bailing or pumping.

Bailing was initially used to develop wells with a well volume of approximately
15 gallons or less. Pre-cleaned, 1 1/4-inch or 3-inch ID PVC bailers were used to
purge water from these wells. Bailers were cleaned with a TSP and distilled water
rinse and then wiped dry prior to use at each well. The bailers were lowered to
different depths within the screened zone and surged to enhance removal of
sediment from the well and adjacent formation. In some instances, the water level
in a well could not be drawn down appreciably or the turbidity of the purged water
did not change significantly. For these wells, and for those wells with a well
volume greater than approximately 15 gallons, either a centrifugal, Moyno, or
submersible pump was used for well development.

The centrifugal and Moyno pumps were generally used for on-site and off-site
overburden and shallow bedrock wells, while the submersible pump was used for
off-site deep bedrock wells. Where the centrifugal and Moyno pumps were used,
3/4-inch OD PVC tremie pipe, previously decontaminated with a TSP and distilled
water rinse, or dedicated pre-cleaned 1/2-inch ID polyethylene hose was attached
to the pump and placed in the well. The pipe or hose was lowered to the bottom of
the well and the intake was raised and lowered during pumping in order to pump
from different intervals within the well screen and improve sediment removal.

An electric, 4-inch-diameter stainless steel Grundfos submersible pump was used for development of the off-site deep bedrock wells, excluding well MW-19D where the Moyno pump was used. The pump, hose, cable, and electric line were decontaminated with a steam cleaner prior to use at each well. The pump was lowered to the bottom of the well for well development purposes.

Fluid removed from the wells by the methods described above was bailed or pumped into 5-gallon pails or 55-gallon drums. Purged water was periodically screened for VOCs by collecting a sample in a glass jar, capping it, and allowing it to equilibrate for approximately 5 minutes before using an HNu or OVA to screen the jar headspace. At wells where the on-site action level of 10 ppm was exceeded, development fluids were containerized in 55-gallon drums. Based upon screening data, containerization of development fluids was required for the following wells: MO-2DR, MO-3SR, MO-5DR, OW-2SR, and OW-4SR. Containerization of development fluids was not necessary at any off-site well location.

A minimum volume requirement was not used as a basis for terminating monitoring well development. At many locations, the effectiveness of monitoring well development was hindered because wells had low yields and were bailed or pumped dry. Development of wells which could not be bailed or pumped dry was more effective and development continued until pH or conductivity measurements of purged water stabilized or the water appeared to be clear of sediment. In most cases, purged water visually appeared to be clear of sediment by the time the water quality indicator parameters stabilized. At wells MO-4S, MW-7S, MW-13S, OW-4SR, and MW-16D this did not occur and development was continued until further improvement of clarity was not apparent.

Well development data sheets, including the date and duration of development, pumping rate, evacuation method, volume of water evacuated, estimated well yield, pH or conductivity measurements, HNu or OVA screening data, total well

depth after development, and well recovery rates were prepared. These data are summarized on well completion reports provided in Appendix B-3. Monitoring well MO-6 was not developed because it was flowing.

## 2.5.2    Aquifer Testing

Three methods were used to estimate hydraulic conductivity of overburden material in the site area. These included empirical methods, laboratory methods, and in situ permeability testing. In situ permeability tests were also conducted in selected on-site shallow bedrock wells to estimate hydraulic conductivity of shallow bedrock.

**Empirical Method**

Grain-size analyses were conducted on seven soil samples collected from borings MO-2DR, MO-3DR, MO-5DR, MW-8S, OW-2SR, OW-4SR, and BE-9 during the monitoring well installation and soil boring programs. These data were used to estimate hydraulic conductivity for overburden materials using the empirical relationship developed by Hazen (Lambe and Whitman, 1969). The Hazen formula is one of several empirical relationships relating soil particle diameter to hydraulic conductivity.

Samples that were selected for grain size analyses were obtained from each of the seven borings at depths beneath the ground water table as observed at the time of drilling, and in some instances the samples correspond to the screened zones of monitoring wells in which hydraulic conductivity was also assessed by laboratory and in situ methods. Table 2-12 summarizes the estimates of hydraulic conductivity made using the Hazen formula. Hydraulic conductivity estimates ranged from $1.9 \times 10^{-4}$ centimeters per second (cm/sec) to $1.0 \times 10^{-2}$ cm/sec. Particle distribution curves used for these analyses and calculations are provided in Appendix B-4.

## Laboratory Methods

Laboratory permeability testing was conducted to supplement estimates from the Hazen analyses and in situ permeability testing conducted at the site. The laboratory method provides estimates of vertical hydraulic conductivity. This approach is expected to produce results generally representative of site conditions in the areas tested, since testing is conducted on an undisturbed sample from the site.

Three Shelby tube samples were collected during the advancement of borings for the monitoring well installation program. The samples were collected from borings by using the drill rig to push a 3-inch OD, 30-inch long, thin-walled Shelby tube into the soil. Upon retrieval of the Shelby tubes, both ends were capped and sealed with wax.

Due to the presence of gravel, cobbles, and boulders encountered in many of the borings, Shelby tubes could only be collected from borings advanced in predominantly fine-grained material. Shelby tube samples were collected from borings MO-2DR, MO-5DR, and MW-13S.

After collection, samples were transported to the soils laboratory in an upright position for analysis using the U.S. Army Corps of Engineers procedure EM 1110-2-1906 for falling head permeameter tests conducted in a triaxial cell. Laboratory reports are provided in Appendix B-4. Results ranged from $5.7 \times 10^{-3}$ cm/sec to $8.7 \times 10^{-3}$ cm/sec and are summarized on Table 2-12. Porosity estimates for these samples ranged from 0.35 to 0.39.

## In Situ Methods

In situ hydraulic conductivity (slug) tests were conducted in selected on-site and off-site overburden and shallow bedrock wells on June 22, 1989 and December 6, 1989 by Balsam personnel. A total of 15 slug tests were conducted,

with ten in overburden wells and five in shallow bedrock wells. Overburden wells tested were MO-2S, MO-3SR, MO-4S, MO-5S, MW-8S, MW-12S, MW-14S, MW-18S, OW-2SR, and OW-4SR. Shallow bedrock wells tested were MO-2DR, MO-5DR, MW-11D, MW-20D, and MW-21D. These wells were chosen for testing to characterize hydraulic conductivity in the study area and within the geologic units monitored by the wells.

Slug testing was conducted by recording static water level, then rapidly raising or lowering the water level in the well and monitoring the response of the water level as it returned toward static conditions. The water level was raised by rapidly lowering a solid stainless steel or cement-filled PVC cylinder into the well to a depth below the static water level. This caused the water level in the well to rapidly rise above the static level. The water level was then monitored and recorded as it returned toward the static level. This test is referred to as a "slug-in" test. Once the water level recovered to within at least 90 percent of the static level, the slug was rapidly removed from the well causing the water level to fall below the static level. The water level was then monitored and recorded as it returned toward the static level. This test is referred to as a "slug-out" test. Both slug-in and slug-out tests were conducted in selected wells. Since the analysis of both methods is conducted similarly and both methods are based on the same equations, it is expected that results should be similar.

Water level measurements were recorded at selected time intervals using a Campbell Scientific CR-10 datalogger and pressure transducer. Decontamination of equipment placed in wells during the tests was conducted prior to and after each use by washing with TSP and potable water followed by a potable water rinse. Dedicated polyethylene rope was used to raise and lower the slugs in each well.

Semi-logarithmic plots of hydraulic head as a function of time during well recovery were constructed and analyzed using methods developed by Bouwer and Rice (1976) and Bouwer (1989). Analytical methods used to estimate hydraulic conductivity are presented in Appendix B-5.

The Bouwer and Rice method was developed assuming ground water flow in porous media. Therefore, application of this method for hydraulic conductivity estimates in fractured bedrock wells may be less accurate than for overburden wells completed in unconsolidated sand and gravel. However, these methods should yield relatively characteristic hydraulic conductivity values in wells screened in shallow bedrock where fracture density is relatively high and fractures are hydraulically connected. In addition, these methods can be used to qualitatively compare relative hydraulic conductivity between shallow bedrock wells.

Analyses of these data were conducted using SLUGIX, a computer graphics and analysis program created by Interprex Ltd. of Golden, CO. SLUGIX allows the user to interactively fit a best curve to the well recovery plots using a ridge regression inversion procedure. The best fit curve is then used to estimate hydraulic conductivity according to the equations presented above. The analytical method accounts for well construction data and aquifer parameters.

Review of the analytical data for the in situ hydraulic conductivity tests is provided in Appendix B-5 and indicates that the correlation between the slug-in and slug-out results at a given monitoring well was good. Therefore, results of slug-in and slug-out tests were generally averaged to estimate hydraulic conductivity at a monitoring well. Based upon this approach, hydraulic conductivity measurements ranged from $2.0 \times 10^{-4}$ cm/sec to $1.2 \times 10^{-2}$ cm/sec in overburden wells and $1.8 \times 10^{-4}$ cm/sec to $1.3 \times 10^{-2}$ cm/sec in shallow bedrock wells. Results are summarized in Table 2-12.

## 2.5.3 Ground Water Sampling

A ground water sampling program consisting of three individual sampling events was conducted to provide data to describe ground water quality in the study area. The three events were conducted in April 1989, September 1989, and December 1989. Each ground water sampling event was conducted concurrently with surface water sampling, stream flow measurements, and with residential well water sampling conducted in the study area by the NHDES.

**Summary of Sampling Events**

The first ground water sampling round was conducted by Balsam personnel from April 18, 1989 through April 21, 1989. Thirty-six wells located within the study area were sampled and ground water samples were analyzed for full HSL parameters, MTBE, THF, and an extensive list of general chemistry parameters including nitrate, nitrite, total organic carbon (TOC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), sulfate, alkalinity and chloride. Samples from selected wells were also analyzed for total and fecal coliform. In addition, ground water from each well was analyzed in the field for temperature, conductivity, and pH.

The second ground water sampling round was conducted by Balsam personnel from September 27, 1989 to October 5, 1989 at a total of 37 wells located within the study area. Based upon the results from the first sampling event and receipt of approval from EPA, ground water samples were analyzed for HSL VOCs and THF. Samples from selected wells were also analyzed for HSL semi-volatile organic compounds, HSL inorganic substances and cyanide. Samples from each well were also analyzed for temperature, pH, and conductivity in the field.

The third round of ground water sampling was conducted by Balsam personnel from December 12, 1989 to December 14, 1989 at a total of 30 wells located within the study area. Based upon results of the prior two sampling rounds, ground

water samples were analyzed for HSL VOCs and THF. Samples from selected monitoring wells were also analyzed for arsenic. Temperature, pH, and conductivity were also analyzed in the field.

Based upon results from the 1989 sampling programs which indicated the presence of VOCs in ground water in the southern boundary area, additional ground water samples were collected from monitoring wells MW-8D and MW-21D in March 1990 by Balsam personnel and the samples were analyzed for HSL VOCs. Only two samples had been collected previously from these wells because well MW-21D was not installed until September 1989 and an insufficient volume of ground water recharged in well MW-8D to collect a sample during the September 1989 sampling round. The additional sampling resulted in a more complete database with which to evaluate conditions in the southern boundary area.

**Sampling Procedures**

Due to the number of locations to be sampled, sampling was generally conducted by two to three two-person sampling teams in order to complete the sampling program within three days. Sampling instructions for each well were summarized on monitoring well sampling protocol forms that were given to each sampling team. These forms provided instructions on the methodologies to be used during sampling activities. In general, sampling teams proceeded from wells located in areas that previous investigations had indicated were not contaminated to areas of expected VOC presence. In addition, wells that recharged slowly, based on data obtained during monitoring well development activities and prior sampling events, were sampled before those which recharged more quickly.

Upon arriving at a monitoring well, the sampling team typically placed a clean piece of 10 foot by 10 foot plastic on the ground near the well to minimize the potential for sampling equipment to come into contact with the soil. Excluding the off-site deep bedrock wells, discussed below, wells were purged using pre-cleaned, dedicated 1-, 1 1/4-, or 3-inch diameter PVC bailers. Purging was conducted until

at least three well volumes of water were evacuated from a well or until the well was bailed dry. Purge water was placed into 5-gallon buckets and a glass jar was periodically half-filled with purge water for headspace screening with an HNu. At wells where the action level of 10 ppm total VOCs was exceeded in the jar headspace, purge water was containerized. During purging, the bailer was lowered to varying depths within the screened or open hole zone where possible in an effort to purge water from the entire length of the well intake.

Due to the depth and the large volume of water present in the off-site deep bedrock wells, Balsam proposed and received approval from EPA to use the following purging methodology in the deep bedrock wells. Deep bedrock wells were purged with a 4-inch-diameter submersible Grundfos stainless steel pump set at approximately 50 feet beneath the static water surface and by pumping the water level in the well down approximately 40 feet or purging the equivalent of three volumes of the first 30 feet of water in the well. The objective of this purging methodology was to remove stagnant water within the cased section of the well and water which may have been affected by its proximity to the water table (e.g., through off-gassing of VOCs, oxidation, etc.). Ground water remaining in the lower portion of the open bedrock well was believed to be representative of formation water quality.

In wells where sufficient well volume existed, ground water samples were obtained by lowering a bailer to the middle of the screened zone or open hole. Several bailer volumes were retrieved and discharged as an additional purging procedure prior to collecting a sample. The bailer was then lowered into the screened zone, slowly raised and lowered approximately 2 feet several times to improve the collection of a sample representative of the screened zone, and the bailer was retrieved to collect a sample. The bailer was not lowered to the bottom of the screened zone or open hole in order to minimize entrainment of sediment. For the deep bedrock wells, samples were obtained by lowering a 3-inch bailer to approximately 180 feet beneath ground surface, the average pump depth in the residential wells.

Samples were poured from the bailers directly into the sample containers provided by the analytical laboratory, with the following two exceptions. A 1-liter or 500-ml polyethylene container was filled for inorganic compound samples and brought to the sample control center (SCC) where the contents were filtered through a 0.45 micron (um) filter and transferred to an equivalent polyethylene bottle. In addition, a 500-ml plastic bottle was filled from each well and brought to the SCC for pH measurements.

Split and duplicate samples were collected by alternately filling bottles for each analysis. EPA split and duplicate samples were collected using sample containers provided by EPA. Table 2-13 summarizes locations of split, duplicate, and field blank samples collected during the three ground water sampling events.

Containers for analytical samples were labeled prior to or just after sample collection with the following information: Balsam project number, sample number, date, and time of collection. During the April 1989 sampling event, samples were collected in the following pre-cleaned containers provided by the analytical laboratory: two 40-ml glass vials with teflon septa (VOCs), two amber 2-liter glass bottles (HSL Pesticides/PCBs and HSL acid/base neutral extractable organic compounds (ABN's)), four 1-liter polyethylene containers (cyanide, nitrate, nitrite, metals, and general chemistry anions), one 125-ml amber glass bottle (total organic carbon (TOC)), one 1-liter polyethylene container (chemical oxygen demand (COD) and biochemical oxygen demand (BOD)), and one 100-ml plastic container (total or fecal coliform). Similar sample containers were used during the September 1989, December 1989, and March 1990 sampling events, except 125-ml glass bottles were used for cyanide analyses, 500-ml polyethylene containers were used for inorganic substances, and some HSL Pesticides/PCB and HSL ABN samples were collected in 4-liter glass bottles.

The glass vials for the VOC analyses and the 125-ml bottles for TOC analyses were pre-preserved with hydrochloric acid by the analytical laboratory. Similarly,

containers for cyanide and inorganic compound analyses were pre-preserved by the laboratory with sodium hydroxide and nitric acid, respectively, while the bottles for COD analyses were pre-preserved with sulfuric acid.

Immediately after sample collection, the temperature and conductivity of the ground water was recorded by placing the temperature-conductivity meter probe into a beaker filled with a sample of the ground water. Ground water temperature, conductivity, odor (when practical), and color were recorded by the sampling team on sample data sheets for each well. Gloves and sampling equipment were decontaminated by scrubbing with a TSP and distilled water solution followed by a distilled water rinse prior to sample collection at each location.

Sample containers were capped immediately after filling, rinsed with distilled water, wiped dry, placed into coolers, and brought to the SCC. Sample data sheets were reviewed for completeness and a check was conducted to verify that the sampling team returned with the appropriate number of filled sample containers for the correct parameters. At the SCC, the ground water pH was measured and recorded on the appropriate sample data sheet. The sample intended for metals analyses was field-filtered using 0.45 um filter paper and a pre-filter and transferred to the appropriate bottle containing nitric acid. The sampling containers were rinsed and wiped dry again before being placed in coolers with ice. Chain-of-custody (COC) forms were then completed for the samples. A signature indicating that the sample containers were accounted for was recorded on the sample data sheets. Personnel handling samples at the SCC changed or washed their gloves with TSP and potable water, before handling sample containers from each well. Samples were stored on ice in coolers and delivered by courier or an overnight delivery service to the analytical laboratory.

## Analytical Summary

Analytical parameters for each sampling round for each monitoring well are summarized in Table 2-14. Ground water pH, temperature, conductivity, and general chemistry parameter results for each monitoring well during each sampling round are summarized in Tables 2-15 and 2-16, respectively. Table 2-17 summarizes HSL compounds detected in ground water during the three sampling rounds. Data validation memoranda and summary analytical reports are provided in Appendices C-3, C-4, and C-5. Complete analytical data packages were previously submitted to EPA and NHDES. Interpretation of the data collected during the ground water sampling program is discussed in Section 4.0.

### 2.5.4 Ground Water and Surface Water Elevation Measurements

During the first day of each ground water sampling round conducted during the RI, ground water elevations were measured in each well using the steel tape and chalk method prior to purging and sampling. Surface water elevations were also obtained during these sampling programs by measuring the difference in elevation between control points on rocks and nails in trees which had previously been surveyed as part of the study area ground control network. Locations for measuring ground water and surface water elevations are shown in Figure 2-9 and Figure 2-10. Results of these measurements are discussed in Section 3.0. Elevation measurements are provided in Appendix B-6.

### 2.6 SURFACE WATER AND SEDIMENT INVESTIGATION

Surface water sampling was conducted concurrently with each of the three RI ground water sampling rounds to assess the extent and nature of potential surface water contamination in the study area. Sediment sampling was conducted during the April 1989 sampling round only, with the samples being obtained at the same locations used to collect surface water samples.

## 2.6.1    Surface Water Sampling

Surface water samples were collected by Balsam personnel on April 20, 1989 at ten locations, designated S-1 through S-10, along the swale, Brook A, and the Exeter River. These locations are shown on Figures 2-12 and 2-13. Surface water sampling was performed concurrently with ground water sampling and stream gauging. Ten surface water samples and one duplicate sample were analyzed for full HSL compounds, MTBE, THF, and an extensive list of general chemistry parameters, including nitrate, nitrite, TOC, COD, BOD, sulfate, alkalinity, and chloride.

The second surface water sampling event was conducted on September 28, 1989. Based upon results of data collected in April 1989, ten surface water samples and one duplicate sample were collected at the same locations used in the April sampling round. These samples were analyzed for HSL VOCs, THF, and HSL Pesticides/PCBs.

The third surface water sampling event was conducted on December 12, 1989. Samples were collected from locations S-1, S-2, S-3, S-5, S-6, and S-10. Based upon a review of previous surface water analytical data, these samples and one duplicate sample were analyzed for HSL VOCs and THF. Insufficient flow was present in the swale to collect samples at locations S-4 and S-9, and sampling of the Exeter River at locations S-7 and S-8 was eliminated due to the absence of VOCs in off-site surface water samples collected during the two previous sampling rounds.

A summary of the parameters analyzed for during each sampling round is provided in Table 2-18. Table 2-19 summarizes sample locations where EPA and Balsam split and duplicate samples were collected.

## Sampling Procedures

Surface water samples were collected at Brook A, drainage swale and Exeter River locations. Samples were collected directly in sampling containers, except VOC samples obtained during the first sampling round which were initially collected in a small-mouthed, one-quart container that was submerged 3 to 6 inches beneath the water surface. These VOC samples were then immediately poured into 40-ml glass vials. During the September and December 1989 sampling rounds, samples were collected directly in 40-ml glass vials. The remaining sample containers were filled by submerging the container 3 to 6 inches beneath the water surface.

Due to the lack of a discrete flow channel and low flow conditions at locations S-4 and S-10, shown in Figure 2-12, a 2-foot square by 1-foot deep hole was dug one week prior to sampling in April 1989 to create a pool deep enough to collect a surface water sample. At these two locations, samples were collected by submerging each container into the surface water pool, with the exception of the vials and the sample containers for the VOC, HSL Pesticides/PCB and HSL ABN compounds, which were filled with water collected using a clean one-quart container.

Due to the shallow depth of surface water flow at the base of the swale near Brook A, a 2-inch-diameter, Schedule 40, PVC pipe was placed in a soil dam constructed at location S-9 in order to collect a sample at this location. The dam directed surface water flow through the PVC pipe creating a stream that could be sampled. At this location, each sample container was filled directly from the PVC pipe discharge. Samples collected at this location contained a significant amount of entrained sediment; this may have resulted in increasing contaminant levels in the water above the actual site concentrations.

Samples collected from the Exeter River at locations S-7 and S-8 (Figure 2-13) were obtained along the south bank upstream and downstream, respectively, of the

wetland area at the confluence of Brook A and the river. The samples were collected in a free flowing area at a depth approximately 6 inches beneath the water surface and from 3 to 5 feet out from the river bank.

Split and duplicate surface water samples were collected by simultaneously submerging and filling the bottles, excluding VOC analysis bottles which were either filled alternately from a clean 1-quart container or simultaneously submerged beneath the water surface.

An additional sample was collected in a 250-ml beaker and the temperature, pH, and conductivity of the water were measured by placing the instrument probes directly into the beaker. Temperature, pH, conductivity, color, and odor of the surface water were recorded in the field on sample data sheets. Temperature, pH, and conductivity measurements are summarized on Table 2-20.

A summary of compounds detected in surface water during the 1989 sampling program is provided in Tables 2-21 and 2-22. Summaries of the validated data and associated data validation memoranda for this program are provided in Appendices C-3, C-4, and C-5. Interpretation of data collected during the surface water sampling program is provided in Section 4.0.

## 2.6.2    Sediment Sampling

Sediment sampling was conducted by Balsam personnel on April 20, 1989 at locations S-1 through S-6, S-9, and S-10 as shown on Figures 2-12 and 2-13. Sediment sampling was performed immediately after collecting surface water samples. Eight sediment samples and one duplicate sample were collected and analyzed for full HSL compounds, MTBE, and THF. Sediment samples were not collected at stations S-7 and S-8 due to their remoteness from the site areas and the fact that three sediment samples were collected upstream along Brook A. The upstream sample results would have indicated whether there was a potential for sediment contamination in the Exeter River resulting from the Mottolo site.

## Sampling Procedures

A spade was generally used to collect sediment at each sampling station from approximately 0 to 3 inches beneath the sediment-water interface. However, at upstream location S-1, the bed was very rocky and the sediment sample was collected from several locations along a 5-foot length of stream bed. Furthermore, to obtain sediment samples from locations S-4 and S-10, 2 to 3-inches of leaves and decaying vegetation had to be removed prior to sediment collection. At sampling location S-9 in the lower swale, sediments had been disturbed by the tires of the drill rig during drilling activities in this area.

Sample containers were filled using a stainless steel spoon. Split and duplicate samples were obtained by alternately spooning sediment into each sample container. EPA split samples were collected at sampling locations S-3, S-6, and S-9. An EPA duplicate sample was collected at sampling location S-3. A Balsam duplicate sample was collected at sampling location S-5. A field blank sample was collected at location S-4 by pouring water provided by the analytical laboratory over the sampling spade after it had been decontaminated by sampling personnel. This sample was analyzed for HSL VOCs, MTBE, and THF.

Labeling and sampling handling methods were similar to those described for the ground water and surface water sampling programs.

## Analytical Summary

Each of the samples collected was submitted for analysis of full HSL compounds, as well as MTBE and THF. A summary of compounds detected in sediments during this program is provided in Table 2-23. A summary of the validated data and associated data validation memorandum for this program is provided in Appendix C-3. Interpretation of the data collected during the sediment sampling program is provided in Section 4.0.

## 2.6.3    Stream Flow Measurement

Measurements of stream flow were attempted during each of the three 1989 sampling rounds at four locations along Brook A and two locations along the swale, designated SF-1 through SF-6, as shown on Figures 2-9 and 2-10.  The only complete set of measurements were collected in April due to field conditions and equipment limitations in September and December.  Stream gauging was conducted at locations where channel cross sections were relatively clear of irregularities and flow was converging.

A pygmy current meter was used to measure stream flow in Brook A, since the water depths were less than 2 feet and the brook has a relatively low flow. Because the width of Brook A at the gauging locations was generally less than 4 feet, the channel cross section was divided into three subsections based upon visual observations of areas of approximately equal flow rates.  Stream flow measurements were recorded over a period of 60 seconds at the approximate center of each subsection at six-tenths of the water depth.  Flow at the two swale gauging locations was diverted through PVC pipes and measured by recording the time it took to fill a graduated beaker.  A summary of the calculated stream flows at locations SF-1 through SF-6 is provided in Table 2-24.  Raw stream gauging data and channel cross sections for Brook A stations are provided in Appendix B-7.

During the September 1989 sampling round, stream flow was also measured with a pygmy current meter.  However, due to a possible meter malfunction and low flow conditions, data collected during this sampling round were considered unrepresentative of actual conditions.  During the third sampling round in December, both the swale and Brook A were covered with thick ice, thereby preventing the measurement of stream flow.

**Base Flow Analysis**

In order to further evaluate the accuracy of the stream gauging data, base flow analyses were conducted for areas within the drainage basin contributing to stream flow at gauging stations SF-1, SF-3, and SF-4. Stream flow volumes at the three stations were calculated using average annual precipitation data and a range of infiltration values considered typically for glacial till and outwash deposits.

Base flow estimates for each of the basin areas, assuming 15 percent and 25 percent infiltration, are provided in Table 2-24, and supporting documentation is provided in Appendix B-7. Stream flow and base flow data are discussed in Section 4.0 with respect to ground water discharge points and volumes.

## 2.7    WETLANDS ASSESSMENT

Balsam conducted a wetlands investigation at the site on October 25, 1989. The primary purpose of the investigation was to identify approximate wetland boundaries and identify wetland types.

Several wetland areas were identified using criteria established in the document, "Federal Manual for Identifying and Delineating Jurisdictional Wetlands," jointly issued by the U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS), EPA and the U.S. Department of Agriculture, Soil Conservation Service (SCS). Regulations presented in the New Hampshire Wetlands Act (RSA 483-A) and the New Hampshire Code of Administrative Rules (Chapters Wt 100 through 700) were also reviewed for their applicability to the investigation. The presentation format of the wetland map and the level of precision used to describe boundaries were modified somewhat from the above documents to satisfy the objectives of the RI/FS, which were to describe the approximate extent and character of wetland areas potentially impacted by contaminants originating from the Mottolo site.

Various wetland indicators were used during the survey to aid in defining wetland areas; however, the presence of wetland vegetation, wetland soils, and wetland hydrology were the primary factors evaluated. Plant species used as wetland indicators included those species designated by the USFWS (1988) by the following categories of prevalence: obligate wetland species occurring 99 percent of the time in wetlands, facultative wetland species occurring 67 to 99 percent of the time in wetlands, and facultative species occurring 34 to 66 percent of the time in wetlands. Soils meeting the criteria of hydric soils were also used as indicators. According to Tiner and Veneman (1987), these are soils which are saturated, flooded, or ponded for a sufficient length of time during the growing season to favor growth of wetland vegetation. Lastly, wetland hydrology, such as the presence of a shallow water table or signs of past flooding, was considered as a wetland indicator.

### 2.7.1    Methodology

Potential wetland areas were initially delineated based upon review of aerial photographs (March 30, 1988), the Mottolo topographic base map (Eastern Topographics, 1989), topographic maps (USGS, 1981), SCS maps and previous site visits. Areas were not field-checked if they were judged to represent non-wetland conditions based upon the above review. Maps from the Federal Emergency Management Agency (FEMA, 1982) were also examined which indicated that locations within the site area have not been designated as floodways or floodplains.

The routine on-site determination method (USACE et al., 1989) was used as guidance for delineating wetland areas. This method included the identification of major plant community types, and the characterization of the vegetation, soils, and hydrology for each plant community type.

A variation of this method was also used because of the apparent low diversity and abundance of understory wetland species. Approximate wetland boundaries, in

these instances, were delineated based largely upon hydric soils, wetland hydrology and canopy. Visual estimates of tree species dominance were also compiled during the survey.

Selected locations were surveyed using methods similar to the intermediate-level on-site determination method (USACE et al. 1989) for delineating wetland boundaries. Areas examined by this method were those in which vegetation appeared diverse or those in which site topography or other features appeared unique to the site. These wetland boundaries were identified by first locating a transect line through an area of abundant and diverse vegetation or through an area of substantial topographic change. Each transect line was generally traversed in a direction away from perennially submerged or baseline areas toward areas without obvious wetland characteristics. A wetland boundary was noted as the point along the transect where one or more of the following were observed: obligate wetland, facultative wetland and facultative indicator species comprising greater than 50 percent of the flora within a one-meter quadrant, the presence of wetland soil types referred to as hydric soils, or evidence of past inundation or saturation of the area by water.

The abundant vegetation along the designated transects permitted a more precise boundary delineation, and, accordingly, these locations were flagged in the field. Boundaries in other locations were based primarily upon reference information and topography, and were considered more approximate than the boundaries at the transect locations. These locations were not flagged in the field.

Vegetation was typically identified in the field using keys and other information presented in Braun (1967), Harlow (1957), Magee (1981), and Niering & Olmstead (1985). Plant indicator status was based upon the entries included in USFWS (1988).

Soil maps prepared by the SCS were used to define areas of poorly drained and very poorly drained soils which meet the criteria of hydric soils. Field confirmation of soil drainage class was conducted by using a spade to dig trenches approximately 20-inches deep, where possible.

Field positions and wetland boundaries were referenced to the site plan with a compass and were located by proximity to prominent site features such as monitoring wells, boulders, and property lines. Most distances were measured with a tape measure; however, some of the greater distances were estimated.

## 2.7.2    Wetland Classification

In order to differentiate between wetland areas, wetlands were classified according to the hierarchical system presented in Cowardin et al. (1979) in which wetland types are described using a progression of terms from the more general to the increasingly specific. The most general categories are systems and subsystems which are followed by classes, subclasses, dominance types, and other specific habitat descripters.

The riverine system is the system most representative of wetlands at the Mottolo site and is generally characterized by a flooded channel dominated by trees and shrubs. The most common subsystem is called lower perennial, with low water velocity and well developed floodplains. Classes represented within the riverine system at the Mottolo site are almost exclusively forested wetlands. The subclass, broad leaf deciduous, can be used to describe the dominant vegetation type, while the water regime can be characterized as permanently flooded.

The palustrine system is also represented at the site, but to a much lesser extent. The system includes non-tidal wetlands characterized by trees, shrubs, and emergent vegetation. Classes represented within the palustrine system include

forested wetlands and moss-lichen wetlands. The subclass for forested wetlands at the Mottolo site is described as broad leaf deciduous. Water regimes are characterized as either saturated or seasonally flooded.

## 2.7.3    Site Conditions

Most trees were foliated at the time of the site visit making identification relatively uncomplicated. However, leaf fall had begun and some sensitive understory vegetation in upland and wetland area had died back due to recent frosts. Grasses and sedges were not readily identifiable without associated flowering parts. The region had experienced heavy rains a week earlier and was likely to reflect saturated conditions. Temperatures during the site visit were approximately 60° F.

## 2.7.4    Field Observations

Field observations were summarized for the areas investigated and are presented in this section. Approximate locations of observations and transect lines used to delineate wetland boundaries are shown on Figure 2-14. A list of flora observed during the wetlands delineation, including the wetland indicator status for each species, is provided in Table 2-25.

Wetland Area A was located approximately 30 feet southwest of monitoring well MW-21D and was characterized by numerous ponded areas. Although the area appeared to be poorly drained, the ponding was unlikely to be a permanent feature since it was not routinely observed during previous site visits. Vegetation consisted primarily of white pine, eastern hemlock, and red maple; little understory was present. Soils were classified as gray Scarboro series with a 6-inch organic layer at the ground surface. Water levels in a 20-inch deep trench recharged quickly to within 6 inches below ground surface in central portions of Area A. The lateral extent of the wetland area was not clearly defined, due to the surface ponding, and boundaries were not flagged.

Wetland Area B, located over 250 feet south of Area A, consisted of a wet marsh approximately 50 feet across at the widest point. Flora characterizing the central portions of the marsh included obligate species such as sphagnum moss, marsh fern, cattail, rushes and sedges. Large trees were absent in the center of the marsh; however, the well-defined marsh perimeter was bordered by abundant swamp azalea, winterberry, speckled alder, red maple, and pin oak. Eastern hemlock, northern red oak, black oak, ash, and white pine were present in areas adjacent to the marsh. Soils were categorized as gray Scarboro muck and characterized by a surficial layer of organic matter at least 6 inches thick. Ponded water was present in some of the lower lying areas, and water was approximately at ground surface in newly dug trenches. The wetland boundary was clearly defined by obligate wetland vegetation and was flagged accordingly.

Wetland Areas C and D were located approximately 100 feet apart where a broad wetland constricts and flows to the north into Brook A. Flora along transects at these locations varied little between locations and laterally from the banks of Brook A to more upland areas of the transects. Very little understory was observed. Typical species included eastern hemlock, white pine, and red maple. Wetland boundaries were flagged approximately 4 feet from either bank of Brook A, according to steeply sloping topography. Soils at the flagging locations were underlain by dense systems of roots, making excavation by hand extremely difficult.

However, water levels in the trenches at these boundaries were noted at approximately 2 inches below ground surface. Soils 10 feet west of Brook A were characterized by up to a 6-inch organic layer underlain by gray, fine to medium sand, but characteristics indicative of periodic inundation such as staining or mottling of the soil were not observed. Therefore, these soils were not considered hydric soils. Ground water was not encountered at depths up to 15 inches below ground surface.

A broad wetland approximately 100 feet across is located south of Areas C and D. This area contains the convergence of two smaller unnamed brooks which form Brook A, one flowing easterly from the vicinity of Area B and one flowing north toward the Mottolo site. Deciduous trees described as common to other wetland areas of an the site were also abundant here. Wetland plants such as sensitive fern were common, especially in the low-lying areas. Wetland boundaries were well represented by topography and were not flagged in the field.

Area E, a forested upland location, was field-checked to determine whether plant species composition changed appreciably from low-lying wetland areas to upland locations. Trees included mainly deciduous species such as red maple, gray birch, white oak, and northern red oak. White pine and eastern hemlock were not as abundant as they were near Brook A. The occurrence of abundant facultative upland species such as white oak, northern red oak, and white pine is the strongest indicator of an improved soil drainage class.

Wetland Area F consisted of a drainage area from the vicinity of the southern portion of the piggery building. The area was not characterized by wetland vegetation; however, it was apparent that this area was often wet as indicated by stained layers and brown mottling in the soils. Soils were gray but lacked the mucky characteristics of soils described for other locations. Approximate wetland boundaries were flagged based largely on soils and hydrology.

Wetland Areas G, H, and I were wetlands with wide floodplains up to 100 feet across. The areas contained facultative wetland plants including sensitive fern, red maple, jack-in-the-pulpit, spotted touch-me-not, and pin oak. Other common flora included facultative and facultative upland plants such as eastern hemlock, tupelo, gray birch, white birch, and upland ferns. Wetland boundaries were based primarily on plant indicator species because of the well-defined understory. Soils were examined to a depth of 6 to 10 inches in several locations, but thick roots prevented examination of soils further below the organic layer. Approximate wetland boundaries along each transect were flagged in the field.

Wetland Area J was characterized by few obligate wetland plants except for mosses and sedges within the uppermost portions of the swale. Buckthorn and swamp azalea were also present. Plants surrounding the swale consisted of colonizing species normally associated with disturbed soils and included goldenrod, asters, grasses, and staghorn sumac. White pine, white birch, red maple, quaking aspen, and pin oak were observed on the slope leading to the clearing in the former drum disposal area. Organic matter present in the surface soils of the clearing appeared to be considerably less than that observed along the swale slope and was likely due to the past excavation and filling of the area. These soils did not meet the criteria for hydric soils. The slope of the ground surface and the history of intermittent flow of surface water through the swale suggests that sufficient hydrological conditions exist to classify the swale as a wetland. However, wetland boundaries were not flagged in the field.

Wetland Area K was located at approximately the western limit of the disturbed portion of the site area and appeared to be near the source of swale surface water flow. The wetlands may have been somewhat artificially broadened to approximately 25 feet in width by former drum removal operations; however, the area has existed in its present condition for a sufficient length of time for wetland plant species to become established. Associated wetland species included grasses, sedges, rushes, moss, and swamp azalea. Plants beyond the wetland boundary consisted of colonizing species as described in Area J, and included goldenrods, boneset, asters, grasses, upland ferns, clover, smartweed, white pine, red maple, quaking aspen, pin oak, and buckthorn. Approximate wetland boundaries were flagged according to plant indicator species and wetland hydrology.

Wetland Area L was located in the Brook A valley to the north of Area I. Flora were similar to those identified along the southern property line of the Mottolo site, where little understory was present, and typical trees included red maple, pin oak, eastern hemlock and white pine. Wetland boundaries were not flagged in the field, but were based largely on soil maps and steeply sloping topography.

Wetland Area M was located in the vicinity of monitoring well MW-13D, where the wetland began to broaden into a wide floodplain. Red maple was more prevalent in this location than in previous locations. Wetland boundaries at this location and north to the property line were not flagged in the field and were based on soil maps and topography.

Wetland Area N was not clearly defined because of extremely saturated conditions on the day of the site visit, but it was apparent that wetland soils were present. Soils were poorly drained and mushrooms and ferns were prevalent to within 20 feet west of the transect. The area was characterized mainly by deciduous trees noted as common throughout the site, such as red maple, gray birch, white birch, and pin oak. In addition, American beech and red pine were also observed. Wetland boundaries were not flagged but were plotted according to soil maps and topography.

## 2.7.5     Review of Soil Maps

Soil maps prepared by the SCS, Rockingham County, were reviewed for consistency with field observations and to aid in classifying wetlands where soils were not examined.

The soil types identified in the SCS maps of the Mottolo site were found to meet the criteria of hydric soils at each defined wetland area and are consistent with field observations. Soils in most of the defined wetland areas on the Mottolo site property have been classified in these maps as Walpole, very fine, sandy loam which is poorly drained and typical of drainageways. Inclusions of Scarboro soils, which range from somewhat poorly drained to poorly drained, are typically scattered throughout the unit and were indicated during field observations. The Scarboro soils exhibit mucky characteristics in Wetland Area B. Inclusions of Squamscott soils are reported as present in the SCS maps, but were not verified in

the field. Soils south of Wetland Area D, within the area of the Brook A convergence, are very poorly drained and have been classified in the SCS maps as Greenwood mucky peat.

## 2.7.6    Summary

Approximately 3 acres of wetlands were identified along the Brook A valley in the Mottolo site area of which approximatley 50 percent is within the Mottolo property. Wetland types at the site were classified into the following two major categories according to the system in Cowardin et al. (1979): forested wetlands/broad leaf deciduous and moss-lichen wetlands. Forested wetlands are represented within the riverine and palustrine systems. Riverine forested wetlands comprise the majority of wetlands from the southern property border at Wetland Area C to the northern property border. These areas are permanently flooded and contain abundant red maple, pin oak, and smaller numbers of eastern hemlock, white pine, ash, and birch. Palustrine forested wetlands are present in Wetland Areas A and N. They are characterized by seasonal flooding and a greater abundance of facultative species than in other defined wetland areas. Moss-lichen wetlands are present at off-site locations to the south of the Mottolo property between the southern property boundary and Strawberry Lane and are typified by saturated conditions and wetland plant species such as sphagnum moss, cattail, and sensitive fern. A large variety of sedges and rushes are also associated with these areas. The drainage swale constitutes an intermittent discharge to Brook A. It is included in the delineated wetlands based on hydrology, since wetland indicator species are not established and soils consist of fill.

Description of wetland boundaries within Wetland Area A, north of Wetland Area M, and west of Wetland Area K was difficult due to the lack of understory vegetation and the wet conditions present during the field investigation. It is likely these boundaries are somewhat more extensive than described.

## 2.8    RESIDENTIAL WELL INVESTIGATION

Due to the close proximity of residential water supply wells to the Mottolo site, sampling of residential wells has been an integral part of investigations conducted by the NHDES since the site was reported in 1979. Throughout this period, the NHDES maintained responsibility for the collection and analyses of residential water supply samples, and, in 1989, the NHDES performed sampling of selected residential wells concurrently with the three RI sampling rounds. The residential home lots and approximate locations of wells included in the 1989 sampling program are shown on Figure 2-15 and are referred to throughout this section.

### 2.8.1    Residential Well Monitoring

In the late 1960's, when the Mottolo piggery was in operation, residential development in the vicinity of the Mottolo site was limited to three homes. One home was located approximately 1500 feet to the southwest (Lot 1), one approximately 1000 feet to the north-northwest along Blueberry Hill Road (Lot 5), and a third home was located approximately 3000 feet northeast of the site (in the vicinity of Lot 52-69). By 1981, eight additional homes had been constructed along Blueberry Hill Road north of the Mottolo site. During the mid-1980's dozens of homes were constructed in the Blueberry Hill Estates development east of Blueberry Hill Road and north of the Mottolo site. During this period, an additional three homes were constructed along Blueberry Hill Road west and southwest of the Mottolo site, with the closest home being located within 400 feet of the site. All of these homes obtain water from bedrock wells located on their property.

The WSPCC began ground water quality monitoring of nearby residential wells for VOCs in May 1979, the month after reporting of the Mottolo site. In 1985, the WSPCC installed a 130-foot-deep bedrock monitoring well, MO-6, approximately 1500 feet north of the Mottolo site on Lot 52-15 along Randy Lane, to provide an additional ground water monitoring location in the residential development. By

1986, when the WSPCC Hydrogeological Investigation Report was issued, the agency had sampled an assorted combination of residential wells on at least twelve occasions and analyzed the samples for VOCs. The WSPCC 1986 report stated that no VOCs had been detected above method detection limits in any of the samples collected to date, including samples from monitoring well MO-6 which has reportedly been a flowing artesian well since installation.

Various combinations of selected residential wells, primarily in the newly constructed Blueberry Hill Estates development were sampled on twenty occasions between August 1986 and February 1989. During this period, trace concentrations of VOCs were detected in samples from some residential wells. The constituent most frequently identified has been THF, although TCA, meta-xylene, toluene, xylene, and MEK have also been reported in samples from some wells.

In anticipation of the detailed monitoring program being implemented as part of the RI, in January 1989 Balsam provided to NHDES a list of twenty residential wells and proposed that they be sampled coincident with the three RI ground water and surface water sampling rounds. NHDES subsequently performed sampling and VOC analysis of samples from these 20 residential wells in April, September, and December 1989, coinciding with the three rounds of RI ground water sampling, with the exception of two wells not being sampled in April and the sampling of two additional wells located southwest of the Mottolo site in September and December. During this period, only trace concentrations of VOCs were detected in samples collected from wells on Lot 52-49 in April and Lot 52-2 in September, both located north of the Mottolo site along Jennifer Lane, and from a well on Lot 52-10 in December located south west of the Mottolo site. The compounds identified in each sample were different and reported at concentrations of less than 2 ppb. VOCs were not detected in any of the other residential well samples obtained during this investigation. Sample analyses detection limits during the 1989 NHDES residential well monitoring program were generally between 0.5 and 5.0 ppb, though detection limits for specific compounds were

sometimes higher, up to approximately 50 ppb. Information regarding detection limits for analyses performed by NHDES prior to 1989 is available from NHDES.

As discussed earlier, seven 225-foot deep bedrock monitoring wells and two overburden monitoring wells within the residential area were installed as part of the RI. These wells were installed to further characterize ground water quality in the subdivision area under more controlled conditions, as well as to support evaluations of the vertical and horizontal nature of ground water flow within the study area.

All of these residential area monitoring wells were sampled during the April and September rounds, with the exception of monitoring well MW-15S which was dry in September. Trace concentrations of one VOC were detected in monitoring well MW-16D in April and monitoring well MW-18D in September. Based upon these results, only monitoring well MW-18D was sampled during the third sampling round. Monitoring well MW-18D was chosen since historical ground water monitoring by NHDES had indicated the presence on some occasions of VOCs in samples from the nearby residential well on Lot 52-45. VOCs were not reported present in the sample collected from monitoring well MW-18D during the December sampling round.

## 2.8.2    Residential Well Construction and Sampling

Data regarding the construction and location of the residential wells have been compiled from several sources including:

o    Questionnaires distributed to homeowners in March 1985 as part of the
       WSPCC investigation and in April 1989 as part of the RI/FS;

o    A "Summary of Well Completion Report" for the Town of Raymond,
       dated July 1989, and provided by the New Hampshire Water Well
       Board;

o   Building permit and septic disposal system approval forms with proposed septic system and well location maps for selected homes; and

o   Visual observations by Balsam personnel of residential well casings and septic system mound locations on residential properties.

The residential wells are typically constructed with 6-inch diameter steel casing driven or spun an average of 15 feet into bedrock. The wells were generally completed using rotary air hammer drilling methods to an average depth of 225 feet below ground surface. Bedrock monitoring wells installed in the residential area were also constructed with a 6-inch diameter steel casing grouted an average of 10 feet into bedrock. The monitoring wells were completed with rotary air hammer methods to a depth of 225 feet in order to provide data compatible with that obtained from the residential wells.

Throughout the course of the Mottolo investigations, residential well water samples have been collected by NHDES personnel. Residential water samples were typically collected from an outdoor spigot or a kitchen tap. The exact location of sample collection at a specific residence may have varied during the monitoring program due to access restrictions. Some residential water supply systems were equipped with water softeners, filters, and possibly other treatment systems which may have affected the quality of the water sampled, although attempts were made by NHDES to collect samples of water prior to passing through these systems. Samples for VOC analyses were collected in 40-ml pre-cleaned glass vials supplied by the NHDES laboratory. Each of these glass vials contained mercuric chloride as a preservative. Samples were chilled on ice, logged in on a chain-of-custody form, and delivered to the NHDES laboratory for analyses. Summary analytical data sheets are provided in Appendix C-7 for the samples collected concurrently with the three 1989 RI sampling rounds. Analytical documentation for samples collected prior to April 1979 is available in NHDES files.

### 2.8.3    Residential Water Supply Analytical Results

Analytical results are summarized for the wells included as part of the 1989 sampling program in Table 2-26. Data for residential wells where VOCs were detected by NHDES prior to the 1989 RI sampling program are also included in this table. Throughout the course of the NHDES monitoring program, analytical methods, sampling methods, and laboratory detection limits have varied. Details regarding these factors for data collected prior to the 1989 sampling program are available in NHDES files.

Historically, there has been little consistency in regard to the locations of residential wells where VOCs have been detected and the compounds identified in the water samples, with the exception of the findings from the wells located on Lots 52-2, 52-21, and 52-45 shown on Figure 2-15. Volatile constituents detected more than once have included THF, TCA, xylenes, meta-xylene, toluene, and MTBE. Of the three rounds of samples obtained from these three wells during the 1989 RI sampling program, VOCs were only detected in a sample from the well on Lot 52-2 in September. The compounds detected in this well, xylenes (1.87 ppb), toluene (1.05 ppb), and m-xylene (1.21 ppb), were identical to those detected in a sample collected by NHDES one year earlier and similar to results of a recent sampling program in June 1990. The only other samples in which VOCs were reported present during the 1989 RI sampling program were obtained in April from Lot 52-49 (1.44 ppb, chloroform) located approximately 3000 feet north of the site, and in December from Lot 52-10 (0.96 ppb, ethylbenzene) located immediately southwest of the Mottolo site. The significance of constituents detected in residential well water samples and potential sources of these constituents are discussed further in Section 4.0.

### 2.9    AIR QUALITY SCREENING

The objective of this activity was to assess air quality in the study area and to identify whether significant concentrations of VOCs were present in on-site

ambient air prior to and during RI field activities. A phased program was developed with the first phase consisting of a site area reconnaissance with an HNu and an OVA. The second phase, which was to be implemented if concentrations of airborne VOCs were detected in the ambient air above the action level during the first phase, included a long-term monitoring program. A sustained total VOC concentration of 15 ppm in the breathing zone was established in the POP as the action level which would warrant a long-term air sampling program. The third phase included conducting air quality screening throughout the course of RI field activities.

## 2.9.1    Air Quality Screening Survey

A site reconnaissance air screening survey was conducted on September 29, 1988 by Balsam personnel. Prior to entering the site, field instruments to be used to perform the air screening were calibrated to a 55 ppm isobutylene standard. The instruments utilized were an OVA and HNu.

Upon entering the site, meteorological readings were obtained. Skies were clear and sunny; winds were from the west-southwest. Wind speeds, measured with a hand-held wind speed indicator, were variable between 0 to 4 miles per hour (mph). The temperature in the open areas around the piggery building was measured at 74 degrees Fahrenheit. In the shaded valley along Brook A, the temperature was measured at 56 degrees Fahrenheit. The National Weather Services office in Concord, New Hampshire reported that the barometric pressure at noon on Thursday, September 29, was 30.49 inches of mercury and falling. There had been no rainfall reported for several days prior to performing the air screening survey.

The field team traversed the site in a south to north direction, from the piggery building to the former disposal area, and from the swale to the staging area, while observing instrument readings and sampling air from 6 inches to 3 feet above the ground surface. Air within a drainage pipe in the swale was also screened by

inserting the instrument probes into the end of the pipe. VOCs were not detected at the locations screened during the survey at concentrations above background levels which were based upon instruments' response in areas upwind of potential source areas (i.e., the former drum disposal area).

The field team then proceeded along the swale down to Brook A in the area where leachate seeps had been noted by previous investigators, north along Brook A to monitoring well couplet MO-5S and MO-5D, and then south along Brook A to a point southeast of the piggery building. Again, VOC concentrations above background levels were not detected by the field instruments in the ambient air from a distance of 6 inches to 3 feet above the ground surface. Prior to switching off the instruments, a post-calibration procedure was performed and it was confirmed that the equipment was still accurately calibrated.

Based on the findings of the screening survey and knowledge of contaminant sources that exist on site, an ambient air quality problem has not been identified at the Mottolo site. Based on this conclusion, implementation of the Phase II long-term air monitoring program was not warranted.

### 2.9.2    Air Monitoring During Field Activities

Air monitoring was performed during on-site RI activities to assess whether field activities and the disruption of potentially contaminated media resulted in VOC releases to air, to monitor breathing zones for worker health and safety evaluation, and to document that on-site ambient air conditions had not changed appreciably from the time of the initial air quality screening survey discussed previously.

Air monitoring was conducted during field activities at the site between October 1988 and December 1989 using either an HNu or an OVA. Air monitoring instruments were calibrated daily prior to field activities, and calibration logs were maintained in accordance with the POP.

Air monitoring was conducted during intrusive activities such as the soil boring program, soil sampling, and the monitoring well installation program. The monitoring instrument was generally used first in an upwind location to assess background conditions. Intermittent monitoring for VOCs was then conducted at the work area in the breathing zone and ambient air concentrations detected above background were noted. The probe of the monitoring instrument was often placed near the surface of excavated soils, sediment, or containers of drilling or well development fluids to monitor for potential releases to air.

VOCs were not detected above background levels in breathing zone ambient air during RI field activities. Furthermore, ambient air quality recorded during on-site activities compared favorably to the initial air quality screening survey results obtained in September 1988.

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Section 3

# 3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Information regarding general physical characteristics of the study area have been discussed in previous RI report sections. Information on the study area meteorology, demography and land use were presented in Section 1.0. Data obtained during field investigations regarding the physical characteristics of the study area were presented in Section 2.0. These data have been integrated in this section to develop descriptions of study area characteristics including hydrology, soils, geology and hydrogeology.

## 3.1   HYDROLOGY

In humid regions, such as the study area, surface water hydrology can generally be conceptualized as three systems: a regional system, an intermediate system and a local system. Due to the considerable recharge of ground water in humid regions, upland areas are generally considered recharge zones with ground water tables sloping toward rivers which serve as discharge points for ground water. In general, upland recharge areas define drainage basin boundaries. The regional hydrologic system is generally controlled by a river or surface water body, and the extent of the system or drainage basin is defined by the land area which drains to the elevation of this predominant surface water body. The regional system that encompasses the RI study area is described as the Exeter River drainage basin, with the river being the major controlling surface water body in the study area. Surface water within this basin is ultimately expected to discharge to the Exeter River.

Intermediate systems can be defined as drainage basins within regional systems which contain smaller streams, brooks and surface water bodies which ultimately discharge to the Exeter River. The majority of the RI study area is within the Brook A drainage basin which can be viewed as an intermediate system. The approximate boundary of the Brook A drainage basin is shown on Figure 3-1.

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Surface water within this basin discharges to Brook A and ultimately to the Exeter River. Brook A is a perennial stream which originates in a wetland area south of the Mottolo property, flows north across the Mottolo property and through the study area for a distance of approximately 5000 feet before discharging to the Exeter River. The portions of the study area not within the Brook A drainage basin include the area west of Blueberry Hill road and the northeastern-most portion of the Blueberry Hill residential area as indicated on Figure 3-1.

Local drainage systems include small drainage basins which are within the intermediate system. Several small local drainages discharge to Brook A within the study area. Local drainages in close proximity to the Mottolo site include the drainage swale located north of the piggery building, a small area of southerly drainage southwest of the piggery building, and a small drainageway located at the toe of the piggery waste landfill. Surface water within the immediate site area should ultimately flow to one of these three local drainageways or directly to Brook A.

The Mottolo site is located on the western flank of the Brook A drainage basin; therefore, rainfall runoff and surface water from the Mottolo site generally flow east toward Brook A. This easterly drainage is most visibly exhibited by the drainage swale which flows east across the Mottolo site to Brook A and primarily drains a relatively level forested area northwest of the former piggery area. In a small area southwest of the piggery building, localized surface water drainage is to the south for approximately 500 feet before turning east and, ultimately, north at the confluence with the headwater area for Brook A. Another minor area of surface water flow originates near the base of the piggery waste landfill and extends north, intersecting Brook A approximately 50 feet south of the drainage swale in the vicinity of the MO-4 well couplet. This area is a wet lowland ranging from 5 to 10 feet in width and flow is often not discernable due to the lack of a discrete channel.

The drainage swale is an intermittent stream exhibiting the greatest flow during the spring and becoming dry during low rain periods in the summer and fall. On some occasions during the summer, flow has been observed in the lower swale area; whereas, the upper swale area was dry. During the winter months, flow in the drainage swale generally freezes. Brook A appears to be perennial, based upon observations of stream flow throughout the RI study period as well as prior site investigations.

As discussed in Section 2.0, in order to further evaluate the hydrologic characteristics of Brook A and the drainage swale, Brook A and drainage swale flow measurements were collected concurrently with the three surface water sampling rounds. However, low flow and freezing conditions prevented the collection of reliable data in September and December 1989, respectively. Therefore, data collected in April were used to assess surface water flow conditions. These data were presented previously in Table 2-24. In addition, Brook A baseflow was estimated at several locations in the site area based upon an assumed annual rainfall rate of 44 inches and infiltration values of 15 and 25 percent for soils developed over sandy glacial till, the predominant overburden material in the study area. The infiltration values were based upon estimates for glacial tills developed by other investigators working in the region.

In April 1989 the Brook A flow at Station SF-1 (see Figure 3-1), located approximately 400 feet upstream of the drainage swale, was measured as 0.5 cubic feet per second (cfs). At Station SF-3, located approximately 100 feet downstream of the confluence of the drainage swale and Brook A, streamflow was measured as 1.3 cfs; streamflow at Station SF-4, located approximately 300 feet downstream of Station SF-3, was measured as 0.7 cfs; and stream flow at Station SF-6, near the northern Mottolo property boundary, was measured as 1.0 cfs. Flow at the base of the drainage swale just prior to discharging to Brook A was measured as 0.02 cfs. These data indicate that Brook A flow was increasing and that the drainage swale was a minor contributor to Brook A flow. The increase in Brook A flow was

attributed to ground water discharge to the brook. However, it was not possible to quantify the magnitude of the contribution due to the observance of Brook A water flowing over the brook banks, creating wetland areas near Stations SF-4 and SF-6, and a potentially anomalous stream flow measurement at Station SF-3.

As a means of further evaluating the overall understanding of ground water discharge to and surface water flow in Brook A, an analytical assessment of Brook A average annual baseflow was performed. Brook A baseflow analytical estimates, assuming 44 inches of annual rainfall and a 25 percent infiltration rate, indicate average annual flow rates at Stations SF-1, SF-3 and SF-4 of 0.12, 0.14 and 0.15 cfs, respectively. The flow rates measured in April 1989 at these stations were higher than the estimated average annual baseflows. This difference in flow rate values was expected because flow rates in the spring typically are much higher than average baseflow rates. Thus, the field-measured and analytically predicted Brook A flow rates were judged to compare favorably. Furthermore, the analytical baseflow estimates also indicate Brook A to be a ground water discharge feature, consistent with the conclusion reached from field measurement data.

Additionally, potentiometric data obtained from monitoring points within the Brook A valley were considered in terms of Brook A flow. As discussed in Section 3.4, vertical upward gradients observed adjacent to Brook A indicate ground water flow is discharging to Brook A, resulting in an increase in flow volume along the brook. These data, in combination with data previously discussed, strongly indicate that Brook A is a gaining stream (i.e., a ground water discharge feature) as it flows through the site area.

## 3.2  SURFICIAL SOILS

A description of study area surficial soils was provided in Section 1.3.3. A generalized map of study area surficial soils is provided as Figure 3-2. The Chatfield, Hollis and Canton soils complex, which covers the majority of the study

area, is characterized as a fine sandy loam with a moderately rapid permeability. Walpole soils are similar to the Chatfield, Hollis and Canton soils except that they are found along the banks of Brook A where drainage conditions are poor. The Greenwood mucky peat is characteristic of wetland deposits in level areas and has very poor drainage. Soil horizon development is relatively shallow over most of the site area with generally less than 1 foot of organic layer development. In the cleared site area, the topsoil was almost entirely removed.

## 3.3   GEOLOGY

A general discussion of the regional geology surrounding the study area was presented in Section 1.3.3. Detailed information regarding the geology of the study area was obtained from a bedrock outcrop study, rock cores, drilling cuttings and literature research during the RI and was presented in Section 2.0. This information was reviewed to develop the description of the study area geology presented in the following sections.

### 3.3.1   Surficial Geology

The Surficial Geologic Map of the Sandown Quadrangle (Gephart, 1987), which includes the study area, indicates the majority of the RI study area is underlain by glacial till deposited directly by glacial ice. The till consists of unsorted to poorly sorted mixtures of clay, silt, sand, pebbles, cobbles, and boulders, and may contain some gravel (Gephart, 1987). Exceptions to this are stratified glaciolacustrine deposits consisting of boulders, cobbles, pebbles, sand and silt, and more recent swamp deposits consisting of muck, peat, silt, sand and minor clay which are mapped along the Exeter River and along Brook A to a point approximately 1000 feet south of the Exeter River. Along Brook A, these deposits are coincident with the swampy area in the Blueberry Hill residential development.

Till is typically described as basal till and ablation till. Basal till was deposited beneath the actively moving glacial ice to form a discontinuous layer of thin compact till. Ablation till was discontinuously deposited during the gradual melting of glacial ice. Ablation till is less compact than basal till and the fine grain fraction is sometimes washed from the deposit resulting in a somewhat stratified appearance.

Descriptions of sediments collected during RI activities indicate that the majority of the till encountered was ablation till. Data from boring and well logs indicate that overburden thickness in the study area is generally less than 20 feet, and bedrock outcrops were observed throughout the area. In addition, a review of boring and well log data reveals that the deposits have a greater heterogeneity than described in the geologic references.

Based upon a review of monitoring well logs, residential well records and seismic refraction data, the overburden thickness in the Blueberry Hill residential area ranges from 0 to approximately 15 feet, except in the vicinity of Brook A where seismic data indicate the overburden thickness is approximately 25 feet at Randy Lane and approximately 45 feet where Brook A passes under Jennifer Lane. Data from monitoring well log MW-18S, located at the intersection of Jennifer and Huckleberry Lanes, indicate the depth to bedrock is 25 feet and the sediments consist of fine to medium sand, and silt and sand. It appears likely that thicker deposits in the vicinity of Brook A have either glaciofluvial and/or glaciolacustrine origins based upon the sandy nature of the deposits and the absence of gravel.

An overburden thickness map (Figure 3-3) for the site area was constructed from several data sources including soil boring logs, seismic refraction profiles, and visual observations of bedrock outcrops. Three geologic cross sections were constructed for the locations shown on Figure 3-4 and are presented as Figures 3-5, 3-6, and 3-7. Cross section A-A' (Figure 3-5), was located to present

geologic information from the southern portion of the site area at monitoring wells MW-20S and MW-20D, across the eastern limit of the former disposal area, to the northern limit of the site area at monitoring wells MW-13S and MW-13D. Cross section B-B' (Figure 3-6) was located to pass through the former disposal area, follow the drainage swale and cross Brook A to monitoring wells MW-12S and MW-12D. Cross section C-C' (Figure 3-7) was located to pass in a northeast-southwest direction from the southern Mottolo property boundary, across the bedrock outcrop area adjacent to the piggery building through the former disposal area, and across the swale to a former drum staging area.

Overburden deposits in the site area generally range from 0 to 15 feet in thickness with the thickest deposits found at the base of the former disposal area south of the drainage swale and in the vicinity of monitoring well MW-8S where the overburden is approximately 20 feet thick. Bedrock was observed to outcrop at a location immediately north of the large concrete pad located west of the piggery building. Based upon seismic refraction data, overburden thickness appears to increase east of Brook A. The overburden thickness north of the swale in the staging area and northwest of the staging area is generally less than 5 feet. This thin mantle of overburden appears representative of these upland areas.

Overburden deposits in the upland site area consist primarily of fine to coarse sand with pockets of gravel. Based upon the number of boring locations where auger refusal was apparently encountered above bedrock, review of historical site photographs, and field observations, the overburden material contains many large cobbles and boulders, characteristic of glacial till deposits. Some sand and gravel fill material was identified in several borings in the former disposal area. This finding is consistent with reports that the former disposal area was partially filled with sand and gravel after drum removal was completed. In addition, the area north of the swale was cleared of vegetation and regraded to establish a drum staging area, extensively disturbing overburden deposits in this area. During the course of the initial investigation and EPA remediation activities, the location of

the drainage swale was moved north to its current location and an earthen berm was constructed at the toe of the former disposal area. Therefore, the possibility exists that more permeable alluvial deposits, as compared to till deposits, are present in the original swale location.

Overburden deposits in the lower swale area and along the west side of Brook A, from monitoring well MO-4S northward to monitoring well MO-5S, consist primarily of a grey fine sand. This sand was also identified at several locations throughout this area where drilling activities had disturbed the thin surficial soil layer and exposed underlying deposits. The predominance of sand in these deposits and the absence of gravel indicates that these deposits are not a till and likely have an alluvial or glaciofluvial origin. Grain-size distribution analyses of soil samples collected from borings MO-5DR and MO-2DR reported the samples as relatively uniform graded sand (see Appendix B-4), further supporting the suggested fluvial origin of these deposits. Deposits observed in borings for monitoring wells MW-12S and MW-13D, located east of Brook A, included fine to medium sand, sand and gravel, and silt. These deposits are somewhat more characteristic of the glacial till that is abundant in this area, although stratification observed in the samples as well as the narrow nature of Brook A valley indicated it is likely redeposition may have occurred through alluvial or fluvial deposition mechanisms.

In general, the overburden soil samples obtained in the site area appear relatively better sorted than most tills in this region. This is primarily exhibited by the relatively small percentage of gravel, clay and silt in the deposits and the presence of stratification identified in some samples. This may indicate that the sediments were slightly reworked during or since deposition, possibly by glacial meltwaters or alluvial processes. Furthermore, the measured hydraulic conductivities for these sediments are somewhat higher than the hydraulic conductivities generally associated with tills due to the small percentage of fines and the sandy nature of the deposits.

### 3.3.2 Bedrock Geology

Several studies were conducted as part of the RI to obtain data to describe the bedrock geology and hydrogeology of the study area, and to provide information to support the evaluation of remedial alternatives. Information regarding the study area bedrock geology was obtained from a review of literature and previous investigation data, and field data collected during the RI including rock cores, geophysical investigation data and bedrock outcrop observations.

Overburden deposits in the study area are underlain by metamorphic and igneous bedrock of the Merrimack Group, as indicated by bedrock outcrop and rock core observations described in Section 2.1.2. Shallow bedrock rock types are shown on the geologic cross sections presented as Figures 3-5 through 3-7. Evidence suggests that bedrock in the vicinity of the study area has been subjected to a complex geologic history which included deformation as a result of various tectonic processes (Boudette, Aleinikoff and Lyons, 1984). As described in Section 1.3.3., several faults have been mapped in the vicinity of the study area. According to the Interim Geologic Map of New Hampshire (Boudette, 1986), the trace of the Flint Hill fault zone which strikes northeast-southwest, passes closest to the study area approximately 5 miles to the northwest. The northeast-southwest strike of the Flint Hill fault is characteristic of the regional structural features; evidence of this trend was observed in bedrock in the RI study area during the course of field activities. These data were presented in Section 2.1.3.

A site area bedrock surface contour map was constructed based upon seismic refraction survey and soil boring data (see Figure 3-8). This map indicates the bedrock surface in the site area generally reflects surface topography. Bedrock surface elevation in the vicinity of the former disposal area ranges from approximately 230 feet above mean sea level (MSL) at the outcrop area northwest of the piggery building to 205 feet MSL at the base of the former disposal area. In the vicinity of Brook A, bedrock surface elevation ranges from approximately

190 feet MSL at the southern property boundary to approximately 160 feet MSL near monitoring well MW-13D at the northern edge of the site area.

Seismic refraction and well log data also indicate that within the residential area, bedrock surface elevation decreases approaching Brook A. The depth to bedrock beneath Brook A in the residential area is generally greater than the depth to bedrock in upland areas, similar to the trend observed in the site area. Seismic data also indicated the presence of a bedrock trough in the vicinity of Brook A that may be the result of joint blocks, preferentially weathered fault zones, or erosional meltwater channels. In addition, the seismic refraction data indicated the presence of either a low velocity zone, fractured zone, or bedrock trough in the vicinity of Brook A along Randy Lane.

### 3.3.3 Lithology

Based upon field observations and review of rock cores, the bedrock geology within the study area is consistent with regional geologic descriptions of the rock types within the Merrimack Group. Seismic refraction studies conducted in the study area indicate that the bedrock is crystalline and seismic velocities were typical of the range expected for Merrimack Group lithologies.

Inspection of rock cores, rock chips and bedrock outcrops within the study area indicated that bedrock within the study area consists of biotite granofels and biotite schist, which have been intruded by sills and dikes of granitic material. Partial melting of the biotite granofels and biotite schist as a result of faulting or intrusion is likely to have produced the slight, swirly foliation and the quartzite layers and lenticular pods observed in the rock. The character of the bedrock at different areas within the study area was similar based upon data collected during the RI.

Biotite granofels identified in rock cores collected in the study area is generally gray, fine to medium-grained and composed of constituents including biotite, feldspar and quartz with lenses of calc-silicate rich rock. The biotite granofels observed was massive (homogeneous in texture) to slightly foliated and typically contained some fracture surfaces coated with iron-staining, an indication of ground water flow through the fracture.

Quartzite interlayers and lenses were often found within the biotite granofels. The quartzite observed was massive, gray, fine-grained quartz. In some samples, quartz mylonite was observed as massive, green, very fine-grained quartzite. Quartz mylonite was identified in rock cores collected from on-site monitoring well location MW-13D and in rock chips at off-site monitoring well location MW-19D. Quartz mylonite is a compact chert-like rock produced by intense metamorphism and is often considered to be indicative of intensive faulting and rock deformation.

Biotite schist and gneiss were observed in rock chip samples collected during air rotary drilling in the residential area. Biotite schist rock chip samples contained black to gray, fine to medium-grained biotite, quartz, feldspar and sulfide minerals. The gneiss observed in rock chip samples was gray to green, medium-grained, with quartz, biotite, chlorite, feldspar and sulfide as major constituents, and was well-foliated.

Pink to gray granite was observed in rock cores, as well as rock chip samples. The granite was massive to slightly foliated, coarse grained and contained major constituents including feldspar, quartz, muscovite, and biotite. Regional geologic studies indicate the granite is likely to have intruded the metamorphic rocks described above. The granite was identified at the top of several cores collected from the Brook A area and interlayered with the metamorphic rocks in the cores collected in the upland areas of the site. The interface between the two rock types contained fracture surfaces which were coated with iron-staining.

### 3.3.4 Secondary Characteristics

Ground water flow through crystalline bedrock is largely influenced by structural features such as joints, faults and irregularities in bedrock surface topography, because the rock itself is essentially impermeable. Features such as extensive weathering, staining or mineralization along fracture or joint surfaces are indicative of ground water flow through these secondary bedrock features. Several tasks were performed to describe the characteristics of these features in the study area.

Low velocity zones in the Brook A area and the residential area were identified in seismic refraction data as described in Section 2.2. These low velocity zones are sometimes coincident with significant changes in bedrock surface elevations and are aligned generally with the orientation of the Brook A valley. The orientation of the Brook A valley and the low velocity zones appear similar to regional fracture orientations associated with the major fault zones in southern New Hampshire as described above.

Results of bedrock outcrop studies in the Mottolo site area indicated the presence of a preferred foliation orientation of 30°, 70° SE as shown on Figure 2-2. Joint orientations measured from outcrops within the study area are shown on Figure 2-3. Two dominant joint orientations are identified at approximately 45 degrees northeast and 120 degrees southeast. Results of a fracture trace analysis conducted by BCI Geonetics as part of the WSPCC investigation indicated the presence of fractures with similar orientation.

Evidence that some fracture features may be significant includes the fracture encountered at 190 feet below ground surface while drilling monitoring well MW-19D located along Blueberry Hill Road which yielded an anomolously high water volume. In addition, seismic data indicated several low velocity zones in bedrock in the vicinity of Brook A which may represent significant fracture zones.

However, data are not available to describe the actual orientations of these features, although it is likely they follow either the northeast-southwest or northwest-southeast preferred joint orientations identified in the bedrock outcrop study and the lineament study.

Based upon examination of shallow (approximately 10 feet) rock cores, the bedrock surface in the site area is slightly weathered and fractures have iron-stained surfaces. The staining generally penetrated the rock less than one-half inch. In most cases, bedrock observed in cores was fresh or slightly weathered, with the exception of cores retrieved from locations MW-9D and MW-11D, which were moderately weathered along fracture surfaces.

In general, fractures observed in the cores were single breaks in the rock, sometimes accompanied by iron staining on the fracture surfaces. Fractures per foot were recorded for rock cores collected during the field programs; these data are shown on the rock coring logs provided in Appendix B-3. In general, the upper 5 feet of the rock cores had a higher number of fractures per foot, between 4 to 16, than the subsequent 5-foot core where less than four fractures per foot were observed. Rock cores obtained from locations OW-4DR and OW-2DR contained less than four fractures per foot over the entire core length. The most significant fracture observed in a core was from location MW-9D, where a near vertical one-quarter-inch fracture was present over a 3-foot length of the core. The hydrogeologic characteristics of the bedrock are discussed further in Section 3.4.

In summary, the bedrock in the study area consists of biotite granofels and biotite schists which have been intruded by sills or dikes of granitic material. The bedrock has been extensively deformed resulting in a predominant northeast-southwest fault and joint orientation and a southeast-northwest joint orientation which was observed in bedrock outcrops in the study area. Between the site area and Brook A, bedrock topography decreases toward the east. Along the Brook A valley, bedrock topography decreases toward the north. Based upon assessment of

rock cores, the shallow bedrock appears to be only slightly weathered. The first 5 feet of bedrock is typically more fractured than the next 5 feet. However, some significant fracture zones may exist, as indicated by the high yielding quartz mylonite zone at a depth of 190 feet in monitoring well MW-19D, and possibly the low velocity zones and bedrock troughs identified in the vicinity of Brook A by the seismic data. The low velocity zones are sometimes coincident with significant changes in bedrock surface elevations and are generally aligned with the orientation of the Brook A valley.

## 3.4  HYDROGEOLOGY

Data concerning regional, study area, and site area hydrogeology were developed to assess the occurrence, direction and rate of ground water flow, potential contaminant transport pathways (discussed in Section 5.0), and to provide sufficient data for development and screening of remedial action alternatives in support of the FS. Hydrogeologic data were collected during RI field activities, from prior site investigations, and from literature review. Remedial investigation activities conducted to characterize study area and site area hydrogeology included geophysical investigations, soils investigations, ground water and surface water sampling programs, a monitoring well installation program, potentiometric head monitoring, and hydraulic conductivity testing.

### 3.4.1  Conceptual Hydrogeologic Model

Topography is a primary factor affecting the development of ground water flow systems. In areas of moderate topographic relief, two or three ground water flow systems generally develop, depending upon the extent of the saturated thickness and hydraulic conductivities of the underlying strata. A schematic drawing which depicts a local system, an intermediate system, and a regional system is shown on Figure 3-9. The hydrogeologic relationship between local, intermediate, and regional systems is important in understanding the occurrence of ground water

and its movement within these systems. In general, ground water flow occurs from topographically higher elevations toward lowland areas. Principal recharge areas occur in topographically higher elevations where the primary component of the ground water flow direction is downward away from the water table, while discharge areas occur in lower elevations where the primary component of ground water flow is upward toward the water table (Freeze and Cherry, 1979). A transition zone, referred to as hinge line, separates recharge areas from discharge areas, as shown on Figure 3-9. In upland recharge areas, imaginary impermeable boundaries, termed ground water divides (Figure 3-9), delineate ground water basins. A ground water basin can be defined for local, intermediate, or regional systems. In humid regions, ground water drainage divides often are coincident with divides for surface water basins since both are typically located at the highest and lowest points of a watershed.

Based upon this information and data collected during the RI, a conceptual model for the ground water flow systems in the Mottolo study area was developed. A discussion of this model is provided below; data to support this model are provided in subsequent sections.

As shown on Figure 1-1, the Mottolo site is located within an area of moderate topographic relief typical of glaciated regions of northern New England. The region containing the Mottolo site is also considered humid. Therefore, overburden and bedrock ground water divides for the study area likely coincide approximately with the surface water divides for the Brook A drainage basin shown on Figure 3-1. Generalized ground water flow directions in study area overburden should ultimately be toward Brook A or its tributaries based upon regional topography. On a regional scale, ground water in bedrock can be conceptualized to flow in response to overburden ground water pressure heads, regional topography, and to regional fracture trends. A more detailed discussion of this conceptual hydrogeologic model is presented below.

Precipitation that infiltrates the soil, and is not lost to evapotranspiration or replenishment of soil moisture, percolates downward to recharge ground water. Depending upon topography, the permeability of the soil and underlying bedrock, and the amount of precipitation, the ground water table may exist within the soil and/or bedrock. Ground water within the overburden would, in part, flow laterally within overburden sediments from higher elevations to lower elevations, discharging as surface water in the valleys. Ground water within the overburden also tends to percolate downward into fractures and joints, where present, at the soil/bedrock interface.

The flow of water through the bedrock is controlled by the frequency and nature of fractures within the bedrock. Water entering bedrock through fractures of higher elevations flows laterally and vertically downward through the bedrock and may discharge from fractures at lower elevations to the overburden and contribute to surface water flow in the valleys. Because ground water flows from higher elevations (e.g., ridges) to lower elevations (e.g., valleys), the ground water flow regime generally coincides with surface water drainage basins. Depending upon the topography, some ground water may underflow local surface drainage systems and discharge to an intermediate or regional surface water feature at a lower elevation. Each of these conceptual hydrogeologic flow paths is shown in Figure 3-9. Ground water flow in bedrock will also respond to fracture systems as these fractures serve as flow paths, although flow in fractures is controlled by potentiometric heads which are typically related to topography.

With respect to the conceptual hydrogeologic model, three principal flow systems can be described within the Mottolo study area. Due to the moderate topographic relief, shallow depth to bedrock, the fractured nature of the bedrock, and the limited saturated thickness of overburden material, local ground water flow systems will develop in overburden and upper bedrock with discharge ultimately to Brook A. Several individual local flow systems may develop in upper bedrock within the study area in areas of topographic relief such as that observed along

the Brook A valley. The Mottolo site is an example of the development of one local flow system within the larger regional area primarily due to topographic effects. On the site, local ground water flow through the upper bedrock zone discharges to the on-site swale or to Brook A.

Beneath the local flow systems, an intermediate ground water flow system likely exists within the moderately fractured bedrock such that on a larger scale, consistent with the study area, ground water in joints and fractures flows toward and into the Brook A valley, and ultimately flows toward the Exeter River located to the north of the site. This intermediate ground water flow system is expected to exist in bedrock beneath the local ground water flow systems located within the study area, including the Mottolo site.

The Lamprey River is located approximately one and one-half miles north of the Exeter River. However, due to the likely decrease in fracture permeability with depth in bedrock, and the similar surface water elevations of Exeter and Lamprey Rivers, it is more likely that the Exeter River serves as the regional ground water discharge point for the study area. Furthermore, an insufficient depth of saturated overburden material exists in the study area for significant deeper flow systems to easily develop in this unit. This is consistent with the development of only local flow systems in areas of pronounced topographic relief (Freeze and Cherry, 1979).

In summary, the conceptual Mottolo study area hydrogeologic model is as follows: The Brook A drainage basin serves as the approximate location of both the area surface water divides as well as the area ground water divides for the overburden and upper bedrock units. Ground water flow within the study area occurs in overburden and bedrock. Local ground water flow systems are present within the study area in overburden and upper bedrock with ground water from both units ultimately discharging to Brook A. An intermediate ground water flow system is likely present beneath these local systems with this bedrock ground water

discharging through overburden to the Brook A valley and ultimately to the Exeter River. A regional flow system underlies the intermediate system with this water also discharging to the Exeter River.

The ground water monitoring network included installation of wells in each of these three flow systems. Wells installed on the Mottolo property monitor the local and intermediate flow systems, whereas wells installed off of the property to a greater depth (225 feet) allow assessment of the regional system.

## 3.4.2 Regional Hydrogeology

The regional topography in the vicinity of the Mottolo study area is dominated by the Exeter River, tributaries to the Exeter River and the large hills that border the Exeter River valley, as shown on Figure 1-1. Consistent with the conceptual hydrogeologic model discussed in Section 3.4.1, ground water in the region is expected to flow radially away from the hills which are regional ground water recharge areas, and toward the Exeter River where regional ground water flow is expected to discharge either directly to the river, or indirectly through ground water discharges to Exeter River tributaries within the study area.

As previously discussed, a relatively thin layer of overburden mantles bedrock within most of the study area. Ground water flow within this overburden is expected to be principally controlled by area topography and, as such, is reasonably well described by the topography shown in Figure 1-1.

Consistent with the conceptual hydrogeologic model presented in Section 3.4.1, ground water flow in study area bedrock is also expected to be principally controlled by area topography. Based upon this premise and the assumptions that the potentiometric surface in study area bedrock is between 10 to 20 feet below ground surface, a conceptualized regional bedrock ground water potentiometric contour map was developed, as shown in Figure 3-10. This figure indicates that

ground water bedrock flow in the study area is driven by three topographic highs located northeast, southeast, and southwest of the site and Brook A. Based upon the potentiometric contours contained in Figure 3-10, regional bedrock ground water flow in the study area is expected to be either toward Brook A or north toward the Exeter River.

### 3.4.3 Mottolo Study Area Hydrogeology

The southern portion of the Mottolo study area is generally bounded by two large hills located south of the Mottolo site, as shown in Figure 1-1. The crest of one hill is located near the southwest corner of the study area, while the crest of the second hill is located near the southeast corner of the study area. Brook A, a tributary to the Exeter River, flows generally north through the middle of the study area.

Consistent with the conceptual ground water flow model, ground water within the Brook A drainage basin, which constitutes much of the study area, generally flows northeast or northwest to Brook A. As previously discussed, ground water flow in the basin is largely controlled by two broad north-south trending ridges on the east and west sides of the basin, and a topographic high south of the basin. Ground water to the west of Brook A and within the basin is expected to flow to the northeast and discharge primarily to Brook A, while ground water on the east side of Brook A and within the basin is expected to flow to the northwest and discharge primarily to Brook A.

Overburden and bedrock ground water flow systems within the study area are expected to be quite similar with respect to direction of flow and are consistent with the regional ground water flow systems described in Section 3.4.2 and shown in Figure 3-10.

## Overburden

Excluding Mottolo on-site monitoring wells, seven overburden monitoring wells were originally proposed to be installed in the study area. Due to the shallow depth to bedrock in this area (see Sections 2.2 and 3.3) and the limited overburden saturated thickness observed during boring advancement, only three overburden monitoring wells, MW-14S, MW-15S and MW-18S, were installed. Potentiometric head data collected in April 1989 from these three wells are shown on Figure 3-11 and indicate that study area overburden ground water generally flows toward and discharges to Brook A. Potentiometric data collected in September and December 1989 indicated similar ground water flow patterns. These data are consistent with and corroborate the presence of local flow systems within study area overburden with ground water ultimately discharging to Brook A. Other conceptual flow regimes were also considered based upon these site data, as well as contaminant distribution data presented in Section 4.0. A review of these data supported the flow regime described above and indicated other flow regimes to be less likely in nature.

The depth to ground water and the saturated thickness in study area overburden, where present, varied temporally and spatially during RI activities. The overburden thickness and proximity to Brook A or its associated wetlands are likely the variables most affecting the magnitude of overburden saturated thickness and fluctuation. Overburden in close proximity to Brook A was more likely to contain some saturated thickness with only moderate potentiometric surface fluctuation; whereas, overburden in upland areas was found not to contain a saturated zone more frequently. Where upland area overburden saturated zones were encountered, the potentiometric surface fluctuations were found to be relatively larger as compared to those observed in overburden deposits near Brook A.

Results from slug tests conducted in monitoring wells MW-14S and MW-18S, presented in Table 2-12, were similar and indicated an average hydraulic conductivity of overburden material in the area monitored by these wells of approximately 6.3 x $10^{-4}$ cm/sec. A bulk porosity of approximately 0.35 to 0.40 was assumed based upon data obtained during physical testing of sediment collected from undisturbed samples for borings MW-13D and MO-5DR (see Appendix B-4). Based upon these data and the similarity of the overburden material observed in borings MW-13D and MO-5DR, as compared to sediment from borings MW-14S and MW-18S, an effective porosity of 0.20 to 0.25 was assumed. This range of effective porosity was deemed representative of sediment observed in study area borings and was consistent with literature values (Todd, 1980; Freeze and Cherry, 1979). A hydraulic gradient across the study area of approximately 0.01 to 0.02 was estimated from Figure 3-11. Based upon this information, the overburden ground water flow rate in the study area is estimated to range between approximately 26 and 65 feet per year.

**Bedrock**

During RI activities, eight additional bedrock monitoring wells were installed within the study area at locations beyond the immediate site area. The locations of these wells (MW-10D, MW-13D, MW-14D, MW-15D, MW-16D, MW-17D, MW-18D, and MW-19D) and potentiometric ground water contours developed based upon April 1989 potentiometric head measurements are shown in Figure 3-12. Similar ground water contours were developed from potentiometric data collected in September and December 1989. The potentiometric contours indicate ground water flow within Brook A valley bedrock is towards Brook A and/or the Exeter River from both the east and west sides of the Brook A valley, which is consistent with the conceptual hydrogeologic model and the direction of ground water flow in the overburden.

At three of the off-site bedrock monitoring well locations, an overburden monitoring well was installed to evaluate the vertical ground water hydraulic gradient (MW-14S/MW-14D, MW-15S/MW-15D, and MW-18S/MW-18D). Well couplet MW-15S/MW-15D is located in an upland area relative to Brook A, and the potentiometric heads measured in these wells during the RI indicated a downward vertical gradient at this location. The flow of ground water from the overburden into the bedrock in upland areas is consistent with the hydrogeologic model. The vertical gradient at monitoring wells MW-14S and MW-14D, located approximately 80 feet west of Brook A at the northern Mottolo property boundary, was calculated to be downward on the three 1989 water level measurement dates, although the difference between the overburden and bedrock head elevation during the September 1989 sampling round was only 0.1 foot. The water levels recorded in September may indicate that wells MW-14S/MW-14D are located in the vicinity of the ground water hinge line, (i.e., where ground water flow transitions from upland recharge to lowland discharge conditions). Additionally, monitoring well MW-14S is located approximately 20 feet northwest of and at a ground elevation 1.5 feet higher than monitoring well MW-14D, which may contribute to the apparent downward vertical gradient observed between these wells.

Well couplet MW-18 is located in a lowland area just east of the wetland area associated with Brook A. Potentiometric levels measured in this well couplet during the three RI sampling rounds indicated an upward vertical gradient. Monitoring well MO-6, also located in a lowland area adjacent to Brook A near Randy Lane, has been a flowing artesian bedrock well since its installation by the WSPCC approximately five years ago. Flowing artesian conditions reflect strong upward vertical hydraulic gradients as evidenced by the discharge of ground water at an elevation greater than ground surface. These data from well MO-6 and well couplet MW-18 are also consistent with the presence of a ground water discharge area in Brook A valley.

### 3.4.4 Mottolo Site Area Hydrogeology

As discussed in Section 3.3, overburden soils thinly mantle the bedrock surface over much of the site area. Ground water occurs in the overburden in the upland portion of the site due to the infiltration of precipitation at the site, the possible migration of ground water through the overburden from topographically higher areas to the west, and the seepage from local bedrock ridges into local overburden-filled bedrock troughs. The site area is located on the upland portion of the western wall of the Brook A valley, such that potential recharge areas to the west of the site area are relatively small; therefore, ground water migrating through the overburden from the topographic higher area to the west is expected to be limited. Most of the ground water in the upland overburden at the site is therefore expected to occur due to on-site precipitation that infiltrates the soil.

### Overburden

Figures 3-13 through 3-15 illustrate site area overburden ground water potentiometric contours which are based upon data collected during the April, September, and December 1989 sampling programs, respectively. These figures indicate a ground water divide beneath and/or west of the piggery building with flow diverging to the north and south of this divide. Based upon these figures, this ground water divide likely moves within the general area seasonally. Bedrock surface contours in the site area, shown on Figure 3-8, indicate that this ground water divide is located in the same general area as a northwest-southeast trending bedrock ridge and the bedrock outcrop area northwest of the piggery building. As overburden is recharged in this area, ground water infiltrates through the overburden and flows down the flanks of this ridge toward the east/northeast or south/southwest. Therefore, two local site area ground water flow systems exist, one to the north and one to the south of the piggery building, hereafter referred to as the ground water flow systems for the former disposal area and the southern boundary area, respectively.

Figure 3-16 illustrates a conceptualized hydrogeologic cross section of the site area ground water flow system through the former disposal area based upon data collected during RI activities. Overburden ground water within this system is recharged in the upland portion of the site by precipitation and upgradient ground water flow. The drainage divide near Blueberry Hill Road forms the western limit of this recharge area, shown in Figure 3-1, while the eastern limit is formed by a hinge line in the vicinity of monitoring well OW-2SR. The northern limit of this recharge area may move seasonally, as discussed below. The area between approximately well OW-2SR and Brook A is the discharge area for overburden ground water in this system.

The extent of saturated overburden in and adjacent to the former disposal area ground water flow system varied between April and December 1989. Monitoring well MW-7S, located west of the piggery building, was dry in December 1989 but contained ground water during other periods of the year. Monitoring well MW-9S, located southeast of the piggery building, was dry in September and December 1989. Ground water was not encountered in borings BE-5, BE-6, BE-7, BE-11, BE-19, and BE-20 (Figure 2-8 and Table 2-5) during January 1989 when these borings were advanced. Ground water was also not encountered in borings BE-21, and BE-23 through BE-25 during September 1989. Visual observations made during boring advancement for monitoring wells MW-11D and OW-3R, during the soil gas program, and results of geophysical studies, suggest that overburden north of the swale area is also dry during portions of the year. This suggests that overburden ground water within this ground water flow system is recharged by precipitation or snowmelt and upgradient ground water flow during wetter seasons, while at other times, the primary recharge source is solely precipitation or snowmelt. During dryer portions of the year, the overburden water table appears to fall to or below the bedrock surface in portions of the areas discussed above. Reference to the geologic cross sections, presented in Figures 3-5 through 3-7, and the bedrock surface contour map, presented as Figure 3-8, indicates that the bedrock surface may partially control the extent of overburden

ground water within this flow system. It appears that overburden ground water principally flows in response to the slope of the bedrock surface. For example, overburden ground water appears to collect and flow within the bedrock troughs shown in these cross sections. Other mechanisms attributing to seasonal changes observed in the occurrence of overburden ground water include greater infiltration capacities of the upper bedrock as compared to low or inconsequential overburden recharge rates during dryer months or an overburden ground water advective flow rate greater than the seasonal recharge rate for the area.

As shown on the ground water contour maps, presented as Figures 3-13 through 3-15, overburden ground water in the former disposal area system (north of the piggery building and generally south of the site drainage swale) flows either toward the north to the swale or toward the east where it discharges to the lower swale, Brook A or Brook A valley wetlands. Overburden ground water flow in this area occurs primarily in response to gravitational forces as it moves along the bedrock surface from higher to lower elevations. This is evidenced by the change in the horizontal hydraulic gradient east of well couplet OW-2SR/OW-2DR which is consistent with a change in the slope of the bedrock surface in this area. There appears to be some hydraulic connection between overburden and upper bedrock in these areas based upon comparable temporal responses in observed overburden and shallow bedrock potentiometric heads. However, potentiometric data from well couplets OW-4 and MW-8 suggest a weaker hydraulic connection between overburden and bedrock suggesting that there may be a more horizontal component of ground water flow at these wells.

Since overburden north of the swale was found to be less than 5 feet thick and appeared dry during the monitoring well installation program, overburden monitoring wells were not completed in this area. However, based upon the local effects of bedrock and ground surface topography, the flow direction of overburden ground water in this area, if present seasonally, will likely be to the south toward

the swale and then east toward Brook A, a pattern similar to that observed for the area south of the swale.

Table 3-1 summarizes vertical gradients calculated in the site area based upon potentiometric head data collected in April, September, and December 1989. A review of these data and Figure 3-16 indicates the presence of downward vertical hydraulic gradients between overburden and bedrock west of approximately well couplet OW-2SR/OW-2DR, and upward vertical hydraulic gradients east of these monitoring wells. This relationship is also depicted on the geologic cross section Figure 3-5. The upward vertical hydraulic gradients occur in an area along the western valley wall of Brook A east of the hinge line near OW-2SR, discussed previously, resulting in ground water discharging from the bedrock to the overburden and ultimately Brook A; in some portions of this area, upward vertical flow gradients were sufficient to support flowing artesian conditions from bedrock wells. Therefore, although the bedrock surface appears to be a primary factor affecting overburden ground water flow toward Brook A west of approximately well OW-2SR, overburden ground water also appears to enter the upper bedrock in areas of fractures or joints due to the downward vertical hydraulic gradients observed.

Figures 3-17 and 3-18 illustrate two cross sections of the brook area near its confluence with the swale, and potentiometric head data collected during April 1989. These figures, combined with the ground water potentiometric contours shown in plan view on Figures 3-13 through 3-15, more fully illustrate components of ground water flow with a resultant discharge to Brook A. Combining Figures 3-17 and 3-18 to approximate a three-dimensional representation of the Brook A valley, primary components of ground water discharge to Brook A occurring simultaneously consist of horizontal flow paths from the east and west (Figure 3-17) and a nearly vertically upward and slightly northerly flow component beneath Brook A (Figure 3-18).

The swale adjacent to the former disposal area also receives some minimal ground water discharge during portions of the year. However, based upon the ground water contour maps presented as Figures 3-13 through 3-15 and the ephemeral nature of the swale observed during RI activities, the swale likely plays a minimal role in affecting overburden ground water flow in the former disposal area excluding localized short term responses to recharge events.

In summary, ground water flow patterns in overburden within the former disposal area system include a vertical component of recharge in the upland portion of the site (west of approximately well OW-2SR), in combination with movement of ground water downslope toward the east and Brook A and discharge of ground water upward from bedrock through the overburden to Brook A in the area east of approximately well OW-2SR. Overburden ground water flow occurs primarily in response to the elevation decrease in the bedrock surface between the recharge and discharge areas.

Potentiometric head data collected on the east side of Brook A from monitoring well couplets MW-12S/MW-12D and MW-13S/MW-13D suggest that a similar ground water flow pattern exists in this area with flow predominantly to the west and discharging to Brook A. Based upon this information, Brook A appears to be gaining in the vicinity of these wells and a significant feature controlling local overburden ground water flow in the site area.

Although relatively fewer overburden monitoring wells exist in the southern boundary area, sufficient data exist to describe the likely ground water flow regime in the area. The western, eastern and southern limits of overburden ground water recharge for this area are expected to be defined by site topography. Because the northern edge of the southern boundary area coincides with a local topographic high, and a ground water divide is associated with this feature, the eastern and western limits of ground water recharge for this area are likely within a narrow band of the developed portion of the site in close proximity to the large

concrete slab located west of the piggery building. The southern recharge area limit should exist between the southern Mottolo property boundary and a marsh which contributes to the headwaters of Brook A, the local ground water discharge point.

The geologic cross sections, presented as Figures 3-5 through 3-7, and the ground water contour maps, presented as Figures 3-13 through 3-15, indicate similar trends in the occurrence and movement of overburden ground water in the southern boundary area as was observed in the former disposal area. Monitoring well MW-9S was dry during September and December 1989 indicating that an area of the overburden southeast of the piggery building is likely dry seasonally. The extent of this dry area is unknown. The remainder of the overburden within the southern boundary area assessed contained ground water during the RI.

The bedrock surface appears to affect this area similarly as compared to the former disposal area in that overburden ground water contours indicate flow along the bedrock surface from higher elevations to lower elevations. General flow directions are consistent with the conceptual model of recharge to overburden above the bedrock ridge in this area with ground water flowing toward the south and southwest in response to the slope of the bedrock surface from this ridge. East of monitoring well MW-9S, overburden ground water, when present, is expected to flow in response to the ground surface and bedrock topography as observed in other areas of the site. Therefore, overburden ground water east of well MW-9S is expected to flow toward the east-southeast and discharge to Brook A. This local flow system is also consistent with the site conceptual model previously discussed.

**Overburden Saturated Thickness**

The saturated thickness of the overburden unit in the site area varied from 0 to approximately 18 feet during 1989 RI activities. The thinner areas of saturated

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thickness were observed in the vicinity of wells MW-7S, MW-9S, MW-21S, and near the concrete pad west of the piggery building. Generally, the areas of greater saturated thickness corresponded to the areas of greater overburden thickness which occurred in the bedrock troughs discussed previously and shown on Figures 3-5 through 3-7. These include areas in the vicinity of wells OW-2SR, MW-8S, MW-12S, and MO-4S. The greatest saturated thicknesses were observed adjacent to Brook A where they ranged from approximately 10 to 18 feet. The range of saturated thickness observed near the former disposal area between April and December 1989 was approximately 11 to 14 feet at well OW-2SR and 7 to 10 feet at well OW-4SR.

**Overburden Hydraulic Conductivity**

Results from aquifer testing previously presented in Section 2.5.2 indicate relatively good correlation between empirical, laboratory, and in situ methods. In order to estimate hydraulic conductivity in the site area, results from the in situ methods were used because these methods incorporate well documented and physically based equations for ground water flow to wells and because hydraulic conductivity estimates from this method represent a larger volume of overburden material as compared to grain size or laboratory analyses. Therefore, in a comparison between empirical, laboratory, and in situ methods, the latter is expected to provide more representative hydraulic conductivity estimates.

Table 3-2 and Figure 3-19 provide hydraulic conductivity estimates in overburden material based upon in situ slug testing results.
Results from slug tests conducted in site area overburden monitoring wells indicated that hydraulic conductivity ranged from approximately $1.2 \times 10^{-2}$ cm/sec to $2.0 \times 10^{-4}$ cm/sec. Hydraulic conductivity estimates for monitoring wells MW-12S, MO-2S, MO-3SR, MO-4S, and MO-5S, all located adjacent to Brook A, were similar, ranging from $2.0 \times 10^{-4}$ cm/sec to $5.6 \times 10^{-4}$ cm/sec with an average of $4.0 \times 10^{-4}$ cm/sec. Hydraulic conductivity estimates for monitoring wells MW-8S

and MW-13S were 4.8 x $10^{-3}$ cm/sec and 5.8 x $10^{-3}$ cm/sec, respectively. Estimates for monitoring wells OW-2SR and OW-4SR, located near the base of the former disposal area, were 6.0 x $10^{-4}$ cm/sec and 1.2 x $10^{-2}$ cm/sec, respectively. The range of two orders of magnitude in hydraulic conductivity observed between monitoring wells OW-2SR and OW-4SR may be due, in part, to prior disturbances of the overburden material during EPA removal actions (e.g., excavation and filling operations) conducted at the site in the vicinity of monitoring well OW-4SR, or to localized alluvial deposits associated with the former swale location. In addition, observations made during the monitoring well installation program indicated that the overburden material in the site area is heterogeneous. Generally, the similarity in the results among monitoring wells in similar site areas is also consistent with data collected during advancement of the soil borings for the monitoring well installation program and visual observations of overburden geology.

**Overburden Transmissivity**

Using hydraulic conductivity estimates from slug testing data and saturated thickness measurements obtained on June 22, 1989, transmissivity values were estimated for the site area. The June 22, 1989 saturated thickness measurements and transmissivity estimates are summarized in Table 3-2, and data are provided in Appendix B-5. Results, which ranged from approximately 6 $ft^2$/day to 300 $ft^2$/day, indicate generally low transmissivity for site area overburden in the areas tested. The limited vertical extent of the saturated thickness is the primary factor affecting overburden transmissivity in the site area.

**Overburden Ground Water Flow Rates**

Flow rates were estimated using Darcy's Law for three areas based upon observed changes in hydraulic gradient. These areas include the upland portion of the site west of approximately well OW-2SR, the area between OW-2SR and the base of

the valley wall, and the area between the base of the valley wall and Brook A.
Hydraulic conductivity values from in situ slug testing previously discussed were
used to estimate the horizontal component to ground water flow rates in the site
area. A range of hydraulic conductivity of $2.0 \times 10^{-4}$ cm/sec to $6.0 \times 10^{-4}$ cm/sec
was used based upon the general range of hydraulic conductivity estimates for
monitoring wells tested in this area. The hydraulic conductivity estimates from
wells MW-13S, OW-4SR, and MW-8S were not used since they appeared to be
somewhat anomalous in comparison to other estimates and likely represent a
rather localized condition. An effective porosity of 0.20 to 0.25 was assumed, as
discussed previously in Section 3.4.3. As discussed previously, and shown on
Figures 3-13 through 3-15, the hydraulic gradient in overburden ground water
varies in three areas of the site. These include the upland portion of the site (west
of monitoring well OW-2SR), along the valley wall, and between the foot of the
valley wall and Brook A. Accordingly, hydraulic gradients were estimated for each
for each of these areas, as shown on Figure 3-20. The hydraulic gradient in the
upland portion of the site through the former disposal area was estimated to range
from 0.08 to 0.14 based upon the ground water contours shown on Figures 3-13
through 3-15. Using potentiometric head data presented on the same figures, the
hydraulic gradient along the western valley wall of Brook A was estimated to
range from 0.21 to 0.27, and the hydraulic gradient between the valley wall and
Brook A was estimated to range from 0.04 to 0.07. Based upon these data, ground
water flow rates in the upland site area, along the valley wall, and between the
valley wall and Brook A were estimated to range, respectively, from approximately
66 feet per year (ft/yr) to 440 ft/yr, 170 ft/yr to 840 ft/yr, and 33 ft/yr to 220 ft/yr.
Assuming linear, horizontal ground water flow, and linear travel distances of
approximately 100 feet from the center of the former disposal area to the top of the
valley wall at monitoring well OW-2SR, approximately 75 feet from the top of the
valley wall to its base, and 60 feet from the valley wall to Brook A, ground water
from the center of the former disposal area should reach Brook A through the
overburden pathway in approximately one to four years. Due to the presence of

localized more permeable deposits present in some parts of the site, actual travel times may be somewhat less than those predicted above.

**Bedrock**

Figures 3-21 through 3-23 illustrate site area bedrock ground water potentiometric contours developed based upon data collected in April, September and December 1989, respectively. As discussed for site area overburden, data indicate a ground water divide beneath and west of the piggery building, with flow to the northeast and south/southwest from this divide, resulting in two upper bedrock flow systems. This ground water divide is also likely to move within the general area in response to seasonal variations in recharge.

Based upon the conceptual model discussed previously and data obtained during the RI, the extent of the recharge areas for the two site area shallow bedrock flow systems should approximate those discussed for the overlying overburden material. Site area bedrock is recharged in the upland portion of the site and possibly from fractures originating further upgradient of the piggery area. Shallow bedrock may be recharged directly in the bedrock outcrop area west of the piggery building.

Ground water in bedrock principally flows through joints and fractures since the crystalline bedrock itself is nearly impermeable. As a result, the ability of the bedrock to transmit ground water is a function of the frequency, aperture, depth and interconnection of bedrock fractures and joints. Generally, the frequency and aperture of fractures within the bedrock decrease with depth. If the bedrock is highly fractured, wells drilled at almost any location are likely to encounter a number of water-bearing fractures. Wells that intercept ground water from a large number of fractures or that encounter a major fracture or joint may yield substantial quantities of water. If the bedrock is not highly fractured, wells drilled into bedrock may encounter very few fractures and will yield little or no water. Based on the seventeen bedrock monitoring wells installed within the site area,

the bedrock at the site is characterized as moderately fractured, though zones with few fractures are present as indicated by monitoring wells MW-8D and OW-4DR, which were found to yield little or no ground water during RI activities.

The bedrock potentiometric ground water contours shown on Figures 3-21 through 3-23 are similar in nature to those identified in site area overburden. The general direction of decreasing potentiometric head is also toward the east and Brook A. Bedrock ground water appears to principally flow upward toward Brook A where it is influenced by the upward vertical hydraulic gradients observed in monitoring well couplets installed in the Brook A valley (Table 3-1). As illustrated on Figures 3-16 and 3-17, bedrock ground water discharges to the overlying overburden unit and ultimately to Brook A. The hinge line, or change in the vertical hydraulic gradient from downward to upward, appears to exist in the vicinity of well couplet OW-2SR/OW-2DR based upon potentiometric head data collected from site area monitoring wells. Between April and December 1989, downward vertical hydraulic gradients ranging from approximately 0.01 to 0.7 (excluding well couplet MW-8S/MW-8D) were observed in upland monitoring wells (Table 3-1), corroborating the potential for shallow bedrock recharge from overburden in this area. The range in vertical hydraulic gradients is due to seasonal fluctuations in both the water table elevation and the bedrock potentiometric head. Potentiometric data from monitoring well MW-8D were not used to generate Figures 3-21 through 3-23 because these data were judged to be anomalous. Well MW-8D recharged extremely slowly following purging during development and during ground water sampling conducted during three separate seasons in 1989. Therefore, it was concluded that this monitoring well was installed in competent bedrock which affects potentiometric data for this well.

East of well couplet OW-2SR/OW-2DR, an upward vertical hydraulic gradient, ranging from approximately 0.02 to greater than 0.3, was observed based upon April, September, and December 1989 data, indicating that ground water discharges from the bedrock into the overburden and Brook A in this area. This

same trend was observed further north in the Brook A valley at well couplet MO-5S/MO-5DR where upward vertical hydraulic gradients ranging between 0.01 and 0.04 were observed between April and December 1989. Data obtained during the RI and the bedrock ground water flow system described above are also consistent with the conceptual hydrogeologic model previously described.

Based upon data describing conditions south of the piggery building, ground water within the shallow bedrock in the southern boundary area is also expected to flow in response to area topography and the decreasing potentiometric levels toward Brook A. As shown on Figure 1-1, less than 1,000 feet south of the southern boundary area is a topographic high with an elevation of 250 feet MSL. Between this topographic high and the southern Mottolo property boundary exists the headwaters of Brook A. Based on the hydrogeologic model developed for the region, local, intermediate, and regional bedrock ground water flows to the north from this topographic high. Site ground water monitoring data indicate local ground water flow beneath the southern boundary area is generally to the south. These two ground water flow systems are believed to converge in the intervening lowland, likely resulting in localized discharge of ground water from the upper bedrock to overburden, and potentially contributing to the creation of a marsh which discharges to the Brook A headwater area.

Thus, it is expected that local upper bedrock ground water flow in the southern boundary area near monitoring well couplets MW-8 and MW-20 is toward the south or southwest to the marsh which contributes to the headwaters of Brook A. Local bedrock ground water not discharging to this marsh is ultimately expected to flow east or southeast in an intermediate system toward the Brook A valley.

As another means of evaluating bedrock flow in the site area, consideration was given to the nature of flow in Brook A. During the course of the RI, as well as during prior site investigations, Brook A has been observed to be continuously flowing, even during dry periods. Thus, although Brook A serves to convey surface

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water runoff, it appears that ground water discharge comprises most of the brook's baseflow. Furthermore, stream gauging measurements indicate that Brook A is gaining, with its flow increasing in part due to ground water discharge to the stream. This observation, in combination with the data previously presented, indicates that Brook A serves as the local and intermediate bedrock ground water discharge point for the site area, as well as for bedrock ground water flow emanating from the eastern portion of the Brook A drainage basin.

**Bedrock Hydraulic Conductivity**

Results from slug testing conducted in bedrock were used to qualitatively assess areas of similar hydraulic conductivity within this unit. Hydraulic conductivity estimates in shallow bedrock ranged from $1.3 \times 10^{-2}$ cm/sec to $1.8 \times 10^{-4}$ cm/sec. Slug tests conducted in wells OW-2DR and OW-4DR were terminated due to the negligible response of water levels in these wells to return toward static conditions. Based upon slug testing results, previously presented in Table 2-12, areas of similar hydraulic conductivity were identified in site area shallow bedrock. The monitoring wells exhibiting greater relative hydraulic conductivities were located primarily within the Brook A valley, excluding well MW-11D which is located in the upland area. This trend is consistent with geophysical results which indicated the potential presence of a fracture zone which may contribute to increased permeabilities in the vicinity of Brook A. The range of estimates corroborate the concept of local variability in hydraulic conductivity in the bedrock.

**Bedrock Ground Water Flow Rates**

Estimates of ground water flow rates in site area shallow bedrock were conducted using Darcy's Law with certain assumptions. The use of Darcy's Law involves the assumption of laminar flow through porous media. Since fracture zones in which ground water flow could become turbulent were not identified in the site area, the assumption of laminar flow appeared valid. In addition, the assumption of an

equivalent porous medium was used to estimate ground water flow rates in site area bedrock. In bedrock, the range of hydraulic conductivities can cover several orders of magnitude as evidenced by the varying slug testing results observed between wells OW-2DR, OW-4DR, and MW-11D (Table 2-12). Similar ranges over orders of magnitude have been shown to exist for bedrock porosity (Randall et al., 1988). However, since ground water flow in bedrock will still respond to the site area hydraulic gradients indicated on Figures 3-21 through 3-23, a range of hydraulic conductivities and porosities were assumed to provide a conservative estimate of ground water flow rates in this unit.

The hydraulic conductivity was conservatively estimated to be the average of slug testing results from monitoring wells MO-2DR, MO-5DR, MW-11D, MW-20D, and MW-21D. This average is $4.6 \times 10^{-3}$ cm/sec. Based upon a review of literature, a range of near surface bedrock porosity consistent with the hydraulic conductivity estimate discussed above is 0.005 to 0.10 (Randall et al., 1988; Aimen et al., 1988; Freeze and Cherry, 1979). Hydraulic gradients in the bedrock ranged between approximately 0.13 and 0.16 during April, September, and December 1989. Based upon this information, estimated bedrock ground water flow rates under the assumptions described above ranged from approximately 17 to 417 feet per day. On this basis, ground water flowing in bedrock below the center of the former disposal area to bedrock below Brook A (approximately 235 linear feet) is estimated to reach Brook A in approximately 1 to 14 days, after which it discharges to overlying saturated overburden and then to Brook A.

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Section 4

# 4.0 NATURE AND EXTENT OF CONTAMINATION

The type, degree and extent of contamination detected in the study area are described in the following sections. For this presentation, the indicator compounds identified in Section 6.0 (Risk Assessment) were used to develop figures depicting concentrations of each of these compounds in soil, ground water, surface water and sediment at each sampling location for the three sampling rounds conducted during the course of the RI. Background on the development of sampling programs, sampling methods, and sample analytical results were presented in Section 2.0.

The frequency of detection and concentration ranges of compounds detected in ground water and surface water samples collected during the RI are presented in Table 4-1. Table 4-1 also lists the location where the maximum concentration was detected in ground water and surface water. Similar data for soil and sediment samples are presented in Table 4-2.

VOCs were the most common class of compounds related to historical waste disposal activities at the site, detected in site media. VOCs were detected in the greatest frequency and highest concentrations in ground water samples and included vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethene, trichloroethene, 1,1,1-trichloroethane, toluene, ethylbenzene, xylenes, and tetrahydrofuran.

As discussed in Section 2.9, a site reconnaissance air screening survey was conducted within the site area prior to commencement of subsequent RI field activities. At the locations screened, VOCs were not detected above background concentrations. Furthermore, throughout the course of on-site RI field activities, air monitoring for VOCs was conducted and VOCs were not detected in breathing zone ambient air. Based upon these findings, more detailed air monitoring was not conducted; therefore, further discussion of air quality is not included in this section.

## 4.1    SOURCES OF CONTAMINATION

Based upon a review of the data presented in the previous sections, one confirmed and three potential sources of contamination were identified within the Mottolo site area.  The confirmed source area was the former drum disposal area where soil and ground water contamination have been identified.  The three potential source areas were the three drum staging areas that were established by EPA during the drum removal activities conducted in 1980 and 1981.  One staging area was located in the upland portion of the site in the cleared area north of drainage swale, the second staging area included the piggery building and the concrete slab south of the building, with the other staging area being located near the southern boundary area, including the large concrete pad located west of the piggery building.  During the course of the RI, and as discussed in this section, the former northern and piggery building drum staging areas were not found to be significant source areas, whereas elevated levels of VOCs were found in ground water flowing beneath the former drum staging area west of the piggery building.  Thus, this potential source area was identified to exist at the site.  These areas are shown on Figure 4-1.  Other significant potential contaminant source areas related to drum disposal and removal activities were not identified during the RI investigatory activities.

In addition to these two contaminant source areas, soil downgradient of the former drum disposal area affected by contaminated ground water may also serve as a residual source of contamination detected in ground water.  The impact of the residually contaminated soils on ground water quality is currently being evaluated as part of a leachability study.  The findings of this study will be included in the Feasibility Study report.

### 4.1.1   Former Drum Disposal Area

During 1980 and 1981, EPA removed a total of approximately 1600 drums and pails containing waste materials from the former drum disposal area.  This area,

which is located between the piggery building and the upper drainage swale, extended over an area approximately 150 feet by 75 feet. Wastes disposed in this area were partially covered with fill material, including some construction debris. During EPA removal activities, drums were exhumed and staged on site until funds were released to transport the wastes off site. Waste characterization data collected during drum removal activities and reviewed by GHR/GZA (1981) and WSPCC (1986) indicated at least the presence of the following waste materials: toluene, methyl ethyl ketone, alcohols, acetates, chromates, lead, zinc, lacquers, turpentine, animal fats, chlorinated compounds and packaged laboratory chemicals. Pesticides, herbicides, PCBs, and oils were not reported as detected.

In addition, approximately 160 cubic yards of contaminated soil were transported off site for disposal. It is presumed that the soil included some contaminated soil removed from the drum disposal area in addition to soils used to construct the drum staging area pads. Data collected during the RI indicate VOC contaminated soil in the former drum disposal area still remains on site. These soils are the principal continuing source of VOCs detected in ground water at the site.

### 4.1.2 Drum Staging Areas

During EPA removal activities, drums were temporarily staged on plastic-lined bermed pads which were constructed in the cleared area north of the drainage swale. Wastes were held in this staging area until the contents of the drums and pails were characterized. Once characterized, the containers were moved to the southern portion of the site, either into the piggery building, onto concrete pads located along the southern side and west of the piggery building, or onto plastic-lined bermed areas adjacent to the concrete pads. Ground water quality data from monitoring wells MW-8S, MW-8D and MW-21D, located in this southern boundary area, indicate the presence of a select number of VOCs in overburden and bedrock ground water. Since data presented in Section 3.0 indicates that ground water in the former drum disposal area flows in a northeasterly direction toward the on-site swale in both the overburden and bedrock, and because the

broad range of VOCs observed in ground water downgradient of the former drum disposal area were not observed in wells downgradient of this staging area, it is unlikely that the former drum disposal area is the source of ground water contamination detected in the MW-8 well couplet and in monitoring well MW-21D. Therefore, it appears that another source area exists or existed in the vicinity of the large concrete pad west of the piggery building. This source is likely related to historical site activities or EPA drum staging operations in this area. Soil gas sampling and soil screening conducted in the vicinity of the concrete pad did not locate an area of VOC soil contamination, indicating that the release which occurred in this area did not result in extensive soil contamination.

Ground water quality data from bedrock monitoring well OW-3R, located in the former northern drum staging area, indicate the presence of low levels of VOCs, as did several soil gas samples from this area. The source of these VOCs may be releases that occurred during drum staging and sampling activities, though results of soil samples collected from this area and analyzed as part of the RI soils investigation did not indicate the presence of VOCs at the locations sampled. The source(s) of VOCs detected in ground water in this area may be small areas of soil contamination not identified during investigatory activities.

### 4.1.3 Piggery Waste Landfill

During the piggery operations from the late 1960's to the mid-1970's, pig wastes and typical domestic waste items (e.g., plastic bags, soda bottles and cans) were disposed of adjacent to the east end of the piggery building. Studies by previous investigators in this area did not reveal contamination related to hazardous materials disposal activities. Data collected during the RI corroborated these previous findings.

## 4.2   SOILS

The nature and extent of contamination in site soil was assessed based upon analytical and field screening results from the soil gas survey (Section 2.3), the soil investigation program (Section 2.4), and the monitoring well installation program (Section 2.5).  Soil gas survey results are shown in Figure 2-7 and are summarized in Table 2-3.  Figure 4-2 summarizes CLP VOC analytical data, Photovac GC screening data, and HNu and OVA field screening data for soil samples collected from borings advanced in the site area during the soil investigation and monitoring well installation programs.  Analytical and field screening data shown in this figure are for total VOCs.  Tables 2-7 and 2-8 present concentrations of individual HSL volatile organic, semi-volatile organic, pesticide/PCB, and inorganic compounds detected in soil samples collected during the soil investigation program.  Appendix C-6 contains individual target VOCs identified by Photovac GC screening.  Due to differences in sample handling practices and analytical techniques, compound specific correlations based on these different analytical techniques were not performed; however, comparisons of total VOC concentrations were used to evaluate data trends.  The data discussed above were used to assess the nature and extent of soil contamination in the former disposal area.

### 4.2.1   Nature of Soil Contamination

Three soil samples obtained during the Phase I soil investigation were analyzed for full HSL parameters, THF, MTBE and TVS.  These results provided the basis for selecting appropriate analyses for subsequent soil investigations.  Since the contaminants reported at the greatest concentrations were VOCs, these compounds were the principal focus of subsequent soils investigations.

### Semi-Volatile Organic Compounds

Significant levels of semi-volatile organic compounds were not identified in site soils.  Results of soil samples analyzed for semi-volatile organic compounds during

the Phase I soil investigation indicate seven semi-volatile organic compounds were detected at concentrations ranging from below detection limits to a maximum of 1.3 ppm. Excluding the presence of 1.3 ppm of bis 2-ethylhexyl phthalate detected in two samples, other semi-volatile compounds detected were reported present below levels of one ppm. Other compounds detected included: 2-methylphenol; 4-methylphenol; 2,4-dimethylphenol; benzoic acid; naphthalene; and butylbenzyl phthalate. Based upon these results, as well as site ground water quality data for these same compounds, semi-volatile organic compounds were not included as analytes in subsequent soil investigation phases.

**Pesticides/PCBs**

Pesticide/PCBs were not detected in the Phase I soil investigation samples analyzed. Based upon these results, waste classification data collected during drum removal, and data collected by WSPCC, these parameters were not included as analytes for subsequent soil investigation phases.

**Inorganic Compounds**

Results from inorganic compounds analyses conducted on soil samples obtained during the Phase I soil investigation indicate that metals were generally present in soil samples at concentrations that are within the ranges expected for soils in the region (see Table 4-3). One exception was antimony which was detected in one sample at an estimated value above the reference range, though not at a level of concern. Although within the reference range, the concentration of lead found in one soil sample (181 ppm) was much greater than that found in the other Phase I soil samples. For this reason, and because lead had previously been identified by EPA in 1980 as being present in some of the on-site drummed waste, lead was retained as an analyte in the Phase II soil investigation. Lead concentrations in soil samples obtained from three Phase II borings ranged from 107 to 118 ppm, while concentrations in the remaining 11 Phase II soil samples that were analyzed were generally less than 15 ppm.

## Volatile Organic Compounds

VOCs including methylene chloride, ethylbenzene, toluene and total xylenes were reported at concentrations ranging from below detection limits to 110 ppm in soil samples analyzed from the Phase I soil investigation. Therefore, VOCs were retained as analytes in subsequent soil investigation phases. CLP analytical data and Photovac GC screening data from the Phase II soil investigation also indicate the presence of VOCs in site soil. VOCs most commonly identified included aromatic hydrocarbons (toluene, xylenes, and ethylbenzene), chlorinated VOCs (trichloroethene, methylene chloride, and tetrachloroethene), and ketones (methyl isobutyl ketone, and acetone). Toluene, ethylbenzene, xylenes, and methylene chloride were generally reported in the greatest concentrations (>1 ppm) and were identified in the greatest number of samples analyzed by CLP and Photovac GC sample techniques. Based upon CLP analytical results, other VOCs were generally reported at concentrations of less than one ppm.

Total VOC concentrations in soil samples analyzed by CLP methods ranged from non-detected to 465.2 ppm; this elevated VOC concentration was reported present in a soil sample from a depth of 2 to 4 feet in soil boring BE-9. Photovac GC results ranged from below detection limits to 664 ppm, while HNu results ranged from less than 1 ppm to 540 ppm. Photovac GC, soil gas, and HNu screening results generally corroborate the CLP analysis VOC concentrations, as indicated on Figures 2-7, and 4-2.

In summary, results from the soil gas survey and the soil investigation programs indicate that VOCs are the primary contaminants present in site area soil and that significant levels of HSL semi-volatile organic, pesticide/PCB, and inorganic compounds were not identified in soil samples collected within the former disposal area.

## 4.2.2 Extent of Soil Contamination

**Former Drum Disposal Area**

CLP analytical data and Photovac GC and HNu screening results from the soil investigations indicate that significant VOC contamination was not identified in soil samples collected from borings BE-5, BE-6, BE-7, BE-8, BE-11, BE-12, BE-16, BE-17, BE-18, BE-19, BE-20, and OW-4SR. However, elevated VOC concentrations were reported in soil samples collected from borings BE-2, BE-3, BE-4, BE-9, BE-10, BE-13, BE-14, BE-15, and OW-2SR. The highest CLP, Photovac GC, and HNu results were observed in one sample collected from boring BE-9 2 to 4 feet below ground surface. This is also the approximate area of the highest VOC responses recorded during the soil gas survey. The highest VOC concentrations were generally observed in soil samples collected at or just above the water table in borings BE-2, BE-3, BE-4, BE-9, BE-10, BE-14, BE-15, and OW-2SR. These borings are all located in the former disposal area or hydraulically downgradient from the disposal area.

Based upon the data presented above, the estimated horizontal extent of soil contamination is shown on Figure 4-2. The estimated extent of the former disposal area, also shown on Figure 4-2, is based upon review of aerial photographs, site photographs, test pit logs, soil boring logs, and visual observations during field activities. However, it appears that a portion of the site disturbed during former site activities (e.g., the area containing borings BE-8, BE-11 and BE-19) was not significantly contaminated by former waste disposal activities. Borings BE-1, BE-2, BE-3, BE-4, BE-9, and BE-10 appear to be located within the directly affected portion of the former disposal area, and borings BE-14, BE-15, OW-2SR, and OW-4SR appear to be located outside the estimated extent of the former disposal area but within a zone of residually affected soils.

The extent of soil contamination shown in Figure 4-2 is characterized as that directly associated with activities in the former drum disposal area (e.g., discharge

of waste liquids), and that residually contaminated by the flow of contaminated ground water through an area hydraulically downgradient of the former drum disposal area to Brook A. Since waste disposal has not occurred at the Mottolo site for at least the last ten years, and since the majority of the VOC source (e.g., leaking drums) was removed almost ten years ago, it is likely that the majority of soil contamination in the residually contaminated area occurred when VOCs were transported with ground water from the disposal area and sorbed to the soil matrix in this downgradient area. Since removal of the majority of the VOC source by EPA in 1980, the residually contaminated area has been slowly flushed with less contaminated ground water, likely resulting in desorption of VOCs from the soil matrix into the ground water. Screening and analytical results for soil samples collected in borings from within the residually contaminated area are consistent with the contaminant transport processes discussed above.

The vertical extent of soil contamination in the former disposal area typically extends from 2 to 4 feet below the ground surface to approximately the bedrock surface, with the most contaminated soil being found near the water table. The volumes of contaminated soil within the former disposal and residually contaminated areas, as shown on Figure 4-2, are estimated to be in the range of 1,400 to 1,900 cubic yards and 2,000 to 2,600 cubic yards, respectively. The latter estimate conservatively assumes that soil contamination within the residually contaminated area extends from the top of the seasonally high water table to the bedrock surface.

**Drum Staging Areas**

Soil gas survey data did not indicate the presence of soil VOC contamination in areas immediately west and south of the piggery building, where drums were staged during EPA removal activities. However, ground water quality data from the southern property area indicated that a contaminant source area appeared to be present in the vicinity of the large concrete pad (Section 4.1). Therefore, five soil borings, BE-21 through BE-25, were completed at locations adjacent to the

concrete pad, and soil samples were collected and screened in the field for VOCs. The soil screening results indicated that VOCs were not detected in the samples at levels above background levels. Similar results were observed in soil samples collected from borings advanced for wells MW-7S, MW-8S, MW-20S, and MW-21S. Thus, it is believed that the source of VOCs observed in ground water from some wells downgradient of this western former drum staging area is soil directly beneath the pad which was impacted by VOCs migrating through cracks in the staging area slab, or soil in close proximity to the pad impacted by VOCs discharging from the slab surface or directly released to the ground.

Soil samples obtained from the former staging area north of the swale did not indicate the presence of soil VOC contamination in this area which warranted additional investigation.

## 4.3    GROUND WATER RESULTS

Three rounds of ground water sampling and analysis were performed as described in Section 1.3 to assess ground water quality in the study area. The first and most comprehensive phase of ground water sampling was conducted in April of 1989. Ground water samples were analyzed for the full HSL compounds, MTBE, THF, and an extensive list of general chemistry parameters including nitrate, nitrite, TOC, COD, BOD, sulfate, alkalinity and chloride. Temperature, conductivity and pH were measured in the field and several samples were also analyzed for total and fecal coliform. During the second phase of ground water sampling in September 1989, ground water analyses included HSL VOCs, THF and arsenic, with some selected samples also being analyzed for HSL ABNs, pesticides/PCBs, inorganic substances, and/or cyanide. Samples collected during the third phase of ground water sampling in December 1989 were analyzed for HSL VOCs, THF and arsenic. Ground water sample analytical results are presented in Tables 2-15, 2-16 and 2-17. Concentration ranges for compounds detected in ground water from monitoring wells during the 1989 RI monitoring program and the frequency of detection are provided in Table 4-1.

The types of contaminants detected in ground water, their concentrations and distribution within the study area are described in the following sections. As described in Section 4.1, results of the three ground water sampling rounds suggest that there are two primary source areas which contribute to ground water contamination; the former drum disposal area and the former southern drum staging area due west of the piggery building near the southern Mottolo property boundary.

### 4.3.1 Nature of Ground Water Contamination

**Volatile Organic Compounds**

HSL VOCs were the HSL compound group most often reported present in ground water samples analyzed during the RI. The VOCs most commonly reported at elevated concentrations include aromatic compounds (toluene, ethylbenzene and xylenes), chlorinated hydrocarbons (vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethene, trichloroethene and 1,1,1-trichloroethane), and tetrahydrofuran (Tables 2-17 and 4-1). Total VOC concentrations reported in site area ground water during the 1989 RI monitoring program are shown on Figure 4-3 and concentrations reported for each of these nine indicator compounds identified above at each sampling location are shown on Figures 4-5 through 4-13. Other VOCs reported were detected at lesser frequencies than the compounds listed above and typically at concentrations less than 100 ppb. Total VOC concentrations reported present in samples from off-site ground water monitoring wells during the 1989 RI monitoring program are shown in Figure 4-14. Because only a small number of VOCs were detected in these samples, and at very low frequencies of detection, individual VOC plots were not prepared for off-site data.

**Semi-Volatile Organic Compounds**

HSL semi-volatile organic compounds were detected in 15 of 47 ground water samples analyzed for HSL ABNs. Concentrations of individual compounds were

reported at less than 15 ppb in all monitoring wells but OW-2SR and OW-4SR where several compounds were detected at concentration up to 130 ppb. The overburden monitoring wells OW-4SR and OW-2SR are located at the base of the former disposal area and adjacent to the swale, respectively. Samples from these monitoring wells also exhibited the greatest concentrations of VOCs reported on site. The semi-volatile organic compounds reported present at low concentrations at other monitoring well locations are commonly found at these levels in the environment and not considered indicators of significant semi-volatile organic compound contamination. For example, bis(2-ethylhexyl) phthalate, an ubiquitous environmental compound associated with plastics, was detected in 11 of 38 samples analyzed in the first sampling round at concentrations ranging from 2 to 15 ppb.

**Pesticides/PCBs**

A total of six HSL pesticides/PCBs were reported present at concentrations less than 0.60 ppb in 5 of the 44 ground water samples analyzed. The only compound reported present in more than one sample was PCB Aroclor 1260 which was reported in three samples (OW-2DR, OW-3R, and MW-11D) from the first sampling round at concentrations less than the contract required detection limit (CRDL) of 1.0 ppb. During the second sampling round, samples collected from these three wells, as well as three other wells in the site area, were again analyzed for HSL pesticides/PCBs. PCBs were not reported present in these second round samples. Based upon the inconsistent results reported for the presence of PCBs in these ground water samples, a more detailed review and evaluation of these and other PCB data was undertaken.

This review included evaluation of all media PCB analyses undertaken as part of the RI, including soils, ground water, surface water, and sediments. PCBs were not reported present in either soil or sediment samples collected during the RI, with the soil samples being obtained directly from the former drum disposal area. PCBs were reported present at very low levels (i.e., less than the contract required

detection limit) in a limited number of ground water and surface water samples. The reported absence of PCBs from both site soils and sediments, which would serve as the source of PCBs in ground water and surface water, respectively, was inconsistent with the reported presence of PCBs in some surface water and ground water. This inconsistency was further born out by the sampling undertaken by EPA and their contractors during the 1980-1981 drum removal operation. During this sampling program, contents of the drums and containers exhumed from the site were analyzed for PCBs. PCBs were not reported present in these waste samples, which is consistent with both the soil and sediment PCB analyses. As such, no site source was identified for the PCBs reported present in some of the RI water samples.

Based upon this finding, a review of the PCB water analyses was undertaken in conjunction with the analytical laboratory. Although PCB contamination was not identified in laboratory blank samples, it was agreed that all of the PCB concentrations reported for surface water or ground water samples were at levels less than the CRDL, a reliable level of quantification, and that as such, only minimal amounts of extraneous PCB contamination resulting from improper sample container preparation, sample extraction and/or sample analysis could result in the reported values.

To evaluate these extraneous PCB contamination mechanisms, the site data were evaluated with respect to sample locations. Of the six surface water samples which were reported to contain PCBs, three of the samples were collected from unaffected, upstream stations (S-1, S-2, and S-9), and one was collected from a station in the Exeter River (S-8). Of the three ground water samples which were reported to contain PCBs, one of the samples was collected from a well with no detectable levels of VOCs (MW-11D). As such, five of the nine water samples which were reported to contain PCBs were collected from areas not shown to be affected by site contamination. Furthermore, the random nature of the location of all nine sample stations also indicated a lack of relationship with respect to site conditions. This evaluation strongly indicated that the source of the PCBs

reported present in the nine water samples was attributed to sample container/laboratory extraneous contamination, and not the Mottolo site. Subsequent resampling of these nine stations, with PCBs not being detected during resampling, further supports this conclusion. Based upon these findings, and the belief that the Aroclor 1260 reported present in first round ground and surface water samples was attributable to laboratory contamination, additional samples were not collected for HSL pesticide/PCB analyses.

**Inorganic Compounds**

In general, inorganic compound analytical results were within ranges commonly occurring in ground water in New England, although some elevated concentrations of compounds commonly related to non-hazardous material landfilling activities (calcium, iron, magnesium, manganese, potassium and sodium) were reported (Tables 2-17 and 4-1). In two cases, elevated levels of parameters such as calcium and sodium in samples from monitoring wells MW-7D and OW-3R appear to be due to Portland cement that was used as grout around the well casings. As discussed previously, arsenic was the only inorganic compound identified as an indicator parameter. Arsenic was reported at levels greater than 50 ppb at seven monitoring well locations near the drainage swale including MO-2S, MO-2DR, MO-3SR, MO-3DR, OW-2SR and OW-4SR. Arsenic concentrations reported in site area ground water and off-site ground water at each sampling location are shown on Figures 4-4 and 4-15, respectively.

**General Chemistry and Field Screening Parameters**

General chemistry analyses conducted at most locations during the first sampling round included alkalinity, nitrite, nitrate, sulfate, and at selected locations included BOD, COD, TOC, fecal coliform and total coliform (Table 2-16). Field screening analyses for most samples was conducted during the three sampling rounds for temperature, pH and conductivity (Table 2-15). In general, review of

these data reveal few trends or anomalies that are not similarly indicated by trends in the VOC data.

The greatest concentrations of nitrate were reported in two samples collected from the residential area monitoring wells MW-17D (2.6 mg/l) and MW-18S (1.1 mg/l) and the only concentration of total coliform reported above 4/100 ml was from a residential area monitoring well MW-16D (88/100 ml). These slightly elevated values may indicate impacts from nearby residential septic disposal systems.

During the 1989 sampling program, values for pH ranged from 4.5 standard units (SU) to 12.4 SU, with typical values in the 5 to 7 SU range. The elevated pH values greater than 10 SU reported in samples from monitoring wells MW-7D, OW-3R and OW-4DR are likely due to Portland cement grout used to seal the well casings. The highest conductivity values recorded were also recorded for the same samples. Other trends identified included the observation that pH values were lower (more acidic) in the overburden than the bedrock and that the values typically increased (became less acidic) from April to December.

### 4.3.2 Extent of Contamination

Based upon the review of ground water quality data collected during the RI, VOCs and arsenic were designated as the principal contaminants present in site ground water. Other contaminants reported present at lower relative concentrations and less frequently (e.g., some HSL metals) generally indicated distribution trends similar to those represented by VOCs and arsenic. Furthermore, the distribution trends of most VOCs detected during the RI ground water sampling program were quite similar in nature with the primary difference in distribution noted between the aromatic and chlorinated compounds. Therefore, figures were prepared which present the distribution of total VOCs, selected specific VOCs, and arsenic based on the average total concentrations reported at each sampling location in samples collected during the 1989 monitoring program. The total VOC distribution plots for overburden and bedrock ground water are presented in Figures 4-16 and 4-20,

respectively. Individual average VOC distribution plots are presented for vinyl chloride and TCE since these were the chlorinated compounds reported at concentrations equal to or exceeding maximum contaminant levels in samples from the MO-5 couplet located near the northern plume boundary (see Figures 4-17, 4-18, 4-21, and 4-22). Individual average distribution plots are also presented for ethylbenzene to represent the general distribution of aromatic compounds in the overburden and bedrock ground water (see Figures 4-19 and 4-23). The arsenic distribution plots for overburden and bedrock ground water are presented in Figures 4-24 and 4-25, respectively.

The following discussions regarding the extent of ground water contamination focus primarily on the distribution of these compounds as related to the former drum disposal area and the southern boundary area. A brief discussion regarding compounds detected in the residential area is also included. Trace or low concentrations of compounds that were not detected in more than one sample from the same monitoring well are not generally included in the following discussions.

**Former Drum Disposal Area**

The distribution of ground water contaminants related to activities in the former drum disposal area can be described using ground water quality data for VOCs and arsenic from monitoring wells located in the site area. The lateral extent of contamination in the overburden ground water extends from the former disposal area north to approximately the drainage swale and east to Brook A, the eastern limit of the overburden plume. The limit of the southern extent of contamination appears to be in the vicinity of monitoring well OW-4S, located approximately 40 feet south of the drainage swale near Brook A, while the northern limit appears to be in the area somewhat north of monitoring well MO-5S, where only low concentrations of VOCs were reported as indicated on Figure 4-16.

Arsenic and VOCs were not reported present in samples from monitoring wells MW-12S and MW-13S located along the eastern bank of Brook A. These findings

are consistent with the overburden ground water flow patterns which indicate ground water should flow east-northeast from the former disposal area to Brook A, and west-northwest from the uplands to the east of Brook A, thereby limiting the eastern migration of contaminants in the overburden beyond Brook A. Based upon the presence of elevated concentrations of total VOCs reported in samples from monitoring well MO-3SR located near the confluence of the drainage swale and Brook A, and low VOC concentrations reported present in samples from well MO-4S located approximately 40 feet to the south of this confluence, the southern boundary of the contaminant plume in the overburden is believed to be in the vicinity of well MO-4S. The rapid reduction in VOCs concentrations observed in this area is consistent with predicted ground water flow directions which indicate an increasing northerly component to ground water flow approaching Brook A which would limit the southern migration of contaminants. The northern boundary of the plume in the overburden is essentially confined to the area west of Brook A and is less abrupt than the eastern and southern boundaries due to the northward component of ground water flow approaching Brook A and the likely contribution of contaminants to the overburden by ground water discharging from the bedrock west of Brook A within the site area. The estimated lateral extent of vinyl chloride, TCE, and ethylbenzene in overburden ground water shown in Figures 4-17, 4-18, and 4-19, respectively, indicate the chlorinated compound, TCE, has migrated the farthest north. The extent of the aromatic compound, ethylbenzene, and vinyl chloride appears more limited to the vicinity of the drainage swale. The estimated extent of arsenic in overburden ground water is shown in Figure 4-24 which indicates elevated arsenic concentrations are limited to the vicinity of the drainage swale.

The lateral extent of contamination in the bedrock related to the former disposal area is similar to the overburden with a few exceptions. The contaminant distribution in the bedrock indicates the eastern boundary of the bedrock plume is in the vicinity of monitoring well MW-12D located on the eastern bank of Brook A. These data indicate that contaminants have migrated somewhat farther east in the bedrock than in the overburden. This is possibly due to the influence of

fractures on bedrock ground water flow directions and the circuitous route ground water within the bedrock may follow before discharging to Brook A. Additionally, the bedrock ground water flow discharge boundary may not coincide exactly with the water table discharge zone expressed by Brook A. The discharge boundary is the imaginary plane where ground water flow originating from two separate recharge areas converges and is forced to rise to a discharge point, in this case Brook A (see Figures 3-16 and 3-17).

Analytical results indicate greater concentrations of VOCs in bedrock monitoring well MO-5DR than in overburden well MO-5S. This could be due to several factors including: contaminated ground water movement from the former disposal area to the northeast through the bedrock into the overburden in the area of monitoring well MO-5S where the water is diluted upon entering the overburden; contaminant attenuation by sorption and other processes upon entering the overburden; and the concentrations reported in samples from well MO-5S not being directly comparable to concentrations reported in samples from monitoring well MO-5DR due to variabilities in bedrock ground water flow to the overburden. Approximately 200 feet north of well couplet MO-5 on the east side of Brook A, VOCs were not reported present in samples of bedrock ground water collected from monitoring well MW-13D. The estimate lateral extent of vinyl chloride, TCE, and ethylbenzene in bedrock ground water shown in Figures 4-21, 4-22, and 4-23, respectively, indicate the chlorinated compounds, vinyl chloride and TCE, have migrated farther north than the aromatic compound, ethylbenzene. The estimated lateral extent of arsenic in bedrock ground water, shown on Figure 4-25, is similar to the overburden, though at lower concentrations.

VOC and arsenic data were reviewed to identify occurrence of significant trends in contaminant concentrations during the 1989 monitoring program. In general, the results of the three rounds of sample data were relatively consistent and trends in the overall data set for 1989 monitoring were not identified. However, some large concentration variations were identified for individual indicator compounds within individual wells. In monitoring well OW-2SR, TCE concentrations dropped from

2,300 ppb in April 1989 to not detected in December 1989, and 1,1,1-TCA dropped from 2,000 ppb in April 1989 to 200 ppb in December 1989. In samples from monitoring well OW-4SR, concentrations of the aromatic compounds toluene, ethylbenzene and xylene dropped from 5,300 ppb, 560 ppb and 1,700 ppb in April 1989 to 7 ppb, 60 ppb and 120 ppb in December 1989, respectively. These reductions in concentrations may be due to seasonal fluctuations in the water table.

In the vicinity of the disposal area, the concentrations of indicator VOCs in the overburden wells OW-4SR and OW-2SR were in most instances greater than the concentrations in the accompanying bedrock wells with the exception of THF, which was reported present at greater concentrations in the bedrock than the overburden throughout the site area. In the lower swale area near Brook A, this trend is not as clear. The compounds reported at greater concentrations in the overburden than the bedrock in the lower swale area include toluene, ethylbenzene, and total xylenes, 1,1,1-TCA and arsenic. Compounds generally reported at greater concentrations in the bedrock include 1,2-DCE, 1,1-DCA, and THF.

The VOCs TCE, 1,2-DCE, 1,1-DCA, vinyl chloride, and THF were reported present at low concentrations in samples from monitoring wells located as far north as well MO-5DR and in some cases well MO-5S. This well couplet MO-5 appears to coincide in close proximity to the northernmost extent of ground water contamination in the bedrock and overburden. These same compounds, with the exception of 1,1-DCA, were also reported present in samples from monitoring well MW-12D.

During the 1989 monitoring program, low concentrations of acetone, THF and a trace of toluene were reported present in samples from monitoring well OW-3R located in the north staging area, whereas no VOCs were reported present in samples from well MW-11D located southeast of well OW-3R. Due to the low level, localized VOC impacts observed in well OW-3R but absent in well MW-11D,

and the different characteristic of VOCs observed in samples from well OW-3R as compared to the VOCs observed in ground water downgradient of the former drum disposal area, it appears that the source of the VOCs observed in proximity to well OW-3R is associated with localized discharges occurring during past site activities or EPA drum staging activities in this area.

**Southern Boundary Area**

The first sampling round analytical data revealed the presence of TCE in samples from monitoring well MW-8S, and 1,2-DCE, TCE and THF in samples from well MW-8D. Since only these three chlorinated compounds and THF were reported at this couplet location, and aromatics were not identified, these data indicated that another source area existed in addition to the former drum disposal area. As previously discussed, the likely source area is located around or beneath the large concrete pad located west of the piggery building where drums were staged by EPA in 1980/81 while awaiting approval for shipment off site. The source may be associated with this drum storage or previous site activities.

In response to this finding, two additional monitoring well couplets were installed to monitor ground water quality along the southern property boundary. The second sampling round analytical results confirmed the presence of the compounds detected in well MW-8 couplet in April, and TCE and 1,2-DCE were detected in new monitoring well MW-21D located approximately 70 feet south of well MW-8D. Monitoring wells MW-8D and MW-21D were resampled in March 1990 to obtain a third data set from each location and the results were similar, with the additional detection of acetone and THF in the sample from well MW-21D. Since concentrations of VOCs have consistently been detected in monitoring wells MW-8D versus MW-8S and similar VOCs have not been reported present in monitoring well couplets MW-20, MW-7 and MW-9, it appears that the source of these VOCs was likely a release in an area of the former drum staging area west of the piggery building. The estimated extent of VOCs in this area is depicted in Figures 4-16 and 4-20. The extent of contamination is believed to be limited to a

small area since a prominent source area was not identified during field investigations.

**Residential Areas**

Nine monitoring wells were installed in the residential area during the RI field program and were sampled as part of the RI 1989 monitoring program to obtain data regarding ground water quality conditions in the residential area. The location of these wells are shown on Figure 2-10. In addition, 22 residential wells located north and southwest of the site area were sampled by NHDES during each RI sampling round. Analytical data indicate that only trace concentrations of contaminants were reported in ground water samples collected from monitoring wells within the residential area and in residential well samples. The only VOCs reported present in ground water samples collected from residential area RI monitoring wells were THF and toluene, reported at approximately 4 ppb and 1 ppb in samples collected from monitoring wells MW-16D and MW-18D, respectively.

Analytical data provided by NHDES for samples collected from residential wells during the three RI sampling rounds indicated that VOCs were reported present at detectable levels in only three samples from three different wells on different sampling dates. Chloroform was reported in the April sample from the well on Lot 52-49, located on Jennifer Lane, at a concentration of 1.5 ppb; xylenes, toluene and ethylbenzene were reported in the September sample from the well on Lot 52-2 located on the corner of Jennifer Lane and Blueberry Hill Road at concentrations of 3 ppb, 1 ppb and 0.5 ppb, respectively; and ethylbenzene was reported in the sample from the well on Lot 52-10, located southwest of the site area on Blueberry Hill Road, at 1 ppb. Figure 2-15 shows the locations of residential wells included in the monitoring program. The results of the most recent NHDES residential well sampling in June 1990 indicate VOCs were detected only in the well located at Lot 52-2 (0.50 ppb toluene, 0.81 ppb xylenes).

Tetrahydrofuran, the VOC detected most frequently in previous (pre-1989) residential area monitoring programs, was not detected in any of the samples collected by NHDES in 1989. Other VOCs detected in more than one sample during the previous NHDES sampling program included TCA, xylenes, meta-xylene, toluene, and MTBE. The source of the VOCs reported in residential wells is not known, though based upon the locations of the residential and monitoring wells where VOCs were detected with respect to the Mottolo site area and the absence of reported compounds in the majority of the wells sampled, it is suspected that the sources of the VOCs are local to these specific wells. Potential sources of these VOCs may include plastic pipe cement, paint thinner, cleaning solvents, gasoline, motor oil, and residential construction materials. The VOCs reported in these samples are major constituents of plastic pipe cement which well pump installers commonly used to assemble pipe used in water supply systems. If this cement is the source of VOCs reported in residential well samples, then reductions in VOC concentrations would be expected with continued well use. Review of well water quality data indicates the frequency of VOC detection has decreased since NHDES began monitoring the residential wells. This reduction would be consistent with pipe cement acting as the source of VOCs found in residential wells. Furthermore, small releases of petroleum products (e.g., motor oil) could be serving as the source of aromatic VOCs in certain wells.

Elevated concentrations of arsenic were reported in samples from RI residential area monitoring well MW-19D at concentrations of 41 and 36 ppb in April and September, respectively. Monitoring well MW-19D is located adjacent to Blueberry Hill Road and may be impacted by road salt contamination which has been linked to elevated arsenic concentrations (Boudette, 1985) though chloride and sodium concentrations reported in ground water at this location do not appear unusually elevated compared to results from other deep residential area monitoring wells. In addition, well MW-19D intersects an extremely productive fracture zone which may also indicate potential communication with a naturally occurring source of arsenic or ground water impacted by nearby residential septic

disposal systems which have been identified as potential sources of elevated arsenic concentrations due to phosphate detergents.

## 4.4    SURFACE WATER AND SEDIMENT

Surface water sampling was conducted concurrently with each of the three RI ground water sampling rounds to assess the nature and potential extent of surface water contamination in the study area, as described in Section 2.6.  Sediment sampling was conducted in Brook A, and the on-site drainage swale during the April 1989 sampling round.  Location of sampling stations are shown on Figure 4-3.

Surface water and sediment sampling stations S-1 and S-4 were chosen to assess upgradient conditions in Brook A and the drainage swale, respectively.  Samples from these locations were also expected to represent background surface water and sediment quality.  Sampling station S-10 was chosen to assess upgradient surface water and sediment quality in a tributary to Brook A at the base of the piggery waste fill area.  Station S-2 was located in Brook A downgradient of the confluence with this drainage but upstream of the Brook A confluence with the drainage swale to provide a comparative basis to ground water quality downstream of the confluence of the on-site swale and Brook A.  Sampling station S-9 was located to assess conditions in the lower drainage swale at a location downstream of the former disposal area but upstream of the confluence with Brook A.  Station S-3 was located to assess surface water and sediment quality in Brook A at a location immediately downstream of the drainage swale confluence.  Stations S-5 and S-6 were located to assess water and sediment quality midway through and at the northern Mottolo property boundary, respectively.

Off-site sampling stations S-7 and S-8 were located to assess surface water quality in the Exeter River upstream and downstream, respectively, of the confluence with Brook A.  Sediment samples were not collected at these locations due to their distant location from the site area.

Ten surface water and eight sediment samples were analyzed during the first sampling round for full HSL VOCs, ABNs, pesticides/PCBs and Inorganic Compounds as well as MTBE, THF and selected general chemistry parameters. As described previously, the first round of surface water and sediment sampling served as the basis for selection for analytical parameters to be employed during subsequent sampling rounds. During the second sampling round, ten surface water samples were collected and analyzed for HSL VOCs and THF; nine samples were also analyzed for HSL pesticides/PCBs, since trace concentrations of one pesticide/PCB compound were detected in several samples from the first sampling round. Due to low flow and freezing conditions in December 1989, the third round of surface water sampling was limited to Stations S-1, S-2, S-3, S-5, S-6 and S-10. Surface water samples collected during the third round were analyzed for HSL VOCs and THF. Field screening data including temperature, pH and conductivity were measured during the three surface water sampling rounds as well. Results of analyses for surface water and sediment samples are provided in Tables 2-20, 2-21, 2-22 and 2-23. Total VOC concentrations and the concentrations of ten specific indicator compounds in surface water and sediment samples are presented in Figures 4-3 through 4-13. In general, data did not indicate significant surface water or sediment contamination beyond the immediate drainage swale area. Based upon these results, descriptions of the nature and extent of surface water and sediment contamination in the study area are presented below.

### 4.4.1 Surface Water Sampling Results

Analytical results of surface water samples collected during the RI indicate that surface water in the immediate area of the lower drainage swale and its confluence with Brook A is impacted by low concentrations of VOCs. Significant concentrations of contaminants related to drum disposal activities were not reported in samples collected in upstream reaches of the drainage swale, Brook A or the piggery waste drainageway, and in downstream reaches of Brook A beyond the site area boundary as well as the Exeter River.

The primary identified source of the VOCs detected in surface water is ground water originating from the former drum disposal area and discharging to the lower drainage swale and Brook A.

The results of surface water samples collected during the RI are presented in Table 2-22. The concentration ranges of compounds detected and frequency of detection in surface water and sediment are summarized in Table 4-1. The occurrence of specific compound suites reported in surface water is discussed in the following sections.

**Volatile Organic Compounds**

Total VOC concentrations detected in surface water samples during each of the three sampling rounds are shown on Figure 4-3. Low levels of total VOCs, 73 ppb and 42 ppb, were detected in the two surface water samples collected from sampling station S-9 located in the swale near its confluence with Brook A. Low or non-detectable levels of total VOCs, 14 ppb, non-detected and 7 ppb, were reported in the three samples collected at station S-3 located in Brook A approximately 60 feet downstream of the drainage swale confluence with Brook A. Of the three samples collected at station S-5 located approximately 300 feet downstream of station S-3, two did not contain detectable levels of VOCs and one contained only 2 ppb of dichloroethane (1,1-DCA).

The VOC compounds reported present in samples from station S-9 included 1,1-DCA, 1,2-DCE, TCA, toluene and TCE. The compound detected at the highest concentration was 1,1-DCA which was detected at 41 ppb and 19 ppb. The remaining VOCs were reported at concentrations less than 15 ppb.

Since the soil berm at the base of the former disposal area limits surface water runoff from this area from directly entering the swale, ground water discharging to the swale is the likely source of VOCs detected in surface water samples collected from station S-9. Contaminated ground water discharging to Brook A, in addition

to surface water discharges from the drainage swale, are the likely sources of VOCs detected in Brook A surface water samples.

## Semi-volatile Organic Compounds

The only HSL semi-volatile organic compound reported in surface water samples collected during the first sampling round was bis(2-ethylhexyl)phthalate, which was detected at 3 ppb and 21 ppb in surface water samples collected from stations S-2 and S-5, respectively. Stations S-2 and S-5 are located in Brook A upstream and well downstream of the drainage swale, respectively. These data did not indicate significant impacts from HSL semi-volatile organic compounds to site surface water.

## Pesticides/PCBs

The only HSL pesticide/PCB compound reported present in surface water samples was Aroclor 1260 at concentrations below 1 ppb in the first sampling round samples from stations S-1, S-2, S-5, S-8, S-9 and S-10; Aroclor 1260 was not reported in the duplicate surface water sample collected at station S-2. These data indicated the presence of Aroclor 1260 at three upstream sampling stations, the Exeter River, and two station downgradient of the former drum disposal area. Even though this distribution of Aroclor 1260 in surface water appeared unlikely because Aroclor 1260 was not reported present in soil or sediment samples analyzed during the RI soil investigations, surface water samples collected from all surface water sampling stations during the second sampling round, with the exception of station S-4, were analyzed for HSL pesticides/PCBs. HSL pesticide/PCB compounds were not detected in these second round samples. On this basis, it was concluded that the presence of Aroclor 1260 in some of the first round surface water samples was attributable to laboratory contamination. Accordingly, HSL pesticide/PCB analyses were not performed in the third round of surface water samples.

## Inorganic Compounds

Surface water samples collected during the first sampling round were analyzed for HSL inorganic parameters. In general, the highest concentrations of inorganic parameters were reported in surface water samples collected in the site area at locations S-9 and S-10. Sampling station S-10 is located in the drainageway at the base of the piggery waste fill area and station S-9 is located in the lower drainage swale just prior to its confluence with Brook A. Compounds reported present at elevated concentrations including calcium, iron, magnesium, manganese, potassium and sodium are commonly associated with fill area leachate. Arsenic was not reported in the surface water samples at concentrations greater than the method detection limit of 2 ppb. Concentrations of these compounds were elevated above the background range established from the results of samples collected at stations S-1 and S-4 located upstream in Brook A and the drainage swale, respectively. The elevated concentrations detected at these locations appear to be related to runoff from the piggery waste fill area and leachate from the former disposal area. However, as discussed in Section 2.6.1, the surface water sample collected from station S-9 contained a significant amount of entrained sediment which may have resulted in reported inorganic compound levels above what was actually representative of surface water quality at this location. Surface water samples collected from Brook A downstream of the piggery waste fill area and on-site swale exhibited slightly elevated concentrations of several inorganic compounds.

Surface water samples collected from the Exeter River at stations S-7 and S-8 contained elevated concentrations of calcium, sodium, magnesium and potassium. Due to similarity in the results of the samples collected from the station located upstream (S-7) and downstream (S-8) of the confluence with Brook A, it appears the these concentrations are not due to contributions from Brook A to the Exeter River but instead, impacts from storm water run off and road salt within the Exeter River drainage basin.

**General Chemistry**

The results of general chemistry analyses including chloride, nitrite, nitrate and sulfate (Table 2-21) and field screening data including temperature, pH and conductivity (Table 2-20) did not indicate significant trends or anomalies related to hazardous materials disposal activities conducted at the Mottolo Site.

**4.4.2 Sediment Sampling Results**

Sediment and surface water samples were collected at the same stations during the first sampling round with the exception of the Exeter River stations where sediment samples were not collected. Sediment sample analyses indicated contaminant distribution trends similar to the surface water samples. These trends included the observation of elevated concentrations of VOCs and inorganic parameters in the lower swale and Brook A in the vicinity of the swale. The results of sediment samples collected during RI are presented in Table 2-23. The concentration ranges of compounds detected and frequency of detection in sediments are summarized in Table 4-2.

**Volatile Organic Compounds**

HSL VOCs were detected in samples collected from locations S-1, S-2, S-3, S-9 and S-10. Total VOCs detected in these sediment samples ranged from concentrations of 8 ppb at location S-3 to 534 ppb at location S-2 as shown on Figure 4-3.

Toluene was reported at 10 ppb in the sediment sample collected at the upstream Brook A station S-1. This result appears to be of little significance when considered in conjunction with other site data. Acetone was the only VOC reported in the sediment sample from location S-10 at 390 ppb. Acetone has been related to piggery wastes in other studies and may be due to the piggery waste fill area; however, acetone was not reported in the three surface water samples collected during the RI from this location or in ground water samples collected

from the nearby monitoring wells MO-4S and MO-4D, indicating this data point may be anomolous.

The sediment sample collected from station S-2, located in Brook A just upstream of the drainage swale, contained the greatest number of VOCs including 1,1-DCA (360 ppb), 1,2-DCE (62 ppb), TCA (64 ppb) and xylenes (48 ppb). 1,1-DCA and TCA were detected at 25 ppb and 27 ppb, respectively, in the sediment sample collected from station S-9 in the lower drainage swale, and TCE was detected at 8 ppb in the sediment sample collected from station S-3 in Brook A downstream of the drainage swale.

The VOCs detected in the sediment samples from stations S-2, S-3 and S-9 are similar to the VOCs reported in ground water in this area; therefore, their presence is likely the result of contaminated ground water discharging to the brook through the stream bed and sorption of associated VOCs onto the sediments.

**Semi-volatile Organic Compounds**

The only HSL semi-volatile compounds reported present in sediment samples were benzoic acid and di-n-butylphthalate, both of which were reported present in the sediment sample collected from station S-9. Di-n-butylphthalate was also reported present in the samples from the two upstream stations S-2 and S-4. Approximately 280 ppb of di-n-butylphthalate were reported in the upstream drainage swale sample collected at station S-4. The specific source of this compound is unknown. However, di-n-butylphthalate is a common environmental contaminant and considered to be ubiquitous due to its widespread use as a plasticizer, which may also account for the reported presence of di-n-butylphthalate in sediment samples collected from stations S-2 and S-9. The source of benzoic acid detected at 170 ppb in the sediment sample from station S-9 is also unknown, although benzoic acid does occur naturally in sediment.

Based upon these analytical results, HSL semi-volatile organic compounds were not judged to be present at significant levels.

**Pesticides/PCB**

The only HSL pesticide/PCB compound reported present in RI sediment samples was 14 ppb of 4,4'-DDE in the sample from location S-10. These results did not indicate significant impacts from pesticide/PCB compounds.

**Inorganic Compounds**

Based upon review of HSL inorganic parameter analyses, it appears that sediments samples, like surface water samples, are most impacted by inorganic compounds at locations downstream of the piggery waste fill area and the former drum disposal area, and include samples from locations S-2, S-9 and S-10. The elevated inorganic compound concentrations reported at station S-10 are likely the result of drainage from the piggery waste fill area. The slightly elevated concentrations of inorganic parameters at station S-2, located in Brook A less than 150 feet downstream of station S-10, are likely due to discharges from the piggery waste drainageway to Brook A. The slightly elevated concentrations of inorganic parameters reported in the sediment sample collected at station S-9 are likely due to surface water run-off from the former drum disposal area and ground water seepage present at this location.

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# 5.0 CONTAMINANT FATE AND TRANSPORT

The fate and transport of contaminants identified at the Mottolo site were
assessed to support the evaluation of remedial alternatives conducted as part of
the FS and to assist in identifying potential receptors for evaluation in the
baseline risk assessment in Section 6.0. This section discusses the fate and
transport of contaminants identified at the site based upon an evaluation of
ground water, surface water, soil and sediment analytical data and information
concerning site physical characteristics presented in previous sections.

Based upon the extent of contamination observed at the Mottolo site, two
contaminant source areas were identified, those being the former disposal area and
the vicinity of the former drum staging area located west of the piggery building.
Data collected to date indicate that the principal contaminant transport pathways
from these source areas are overburden bedrock ground water and surface water.
Based upon air monitoring data discussed previously and the subsurface nature of
the original contaminant releases, contaminant transport in air was not identified
as a significant pathway at the site.

The following includes a discussion of the nature of the contaminant releases from
source areas, descriptions of migration pathways, factors affecting contaminant
transport in site media, and the fate of contaminants.

## 5.1    CONTAMINANT RELEASES

Based upon site history and observations made during the EPA drum removal
program, it is reasonable to assume that the most significant releases to the
former disposal area were liquid wastes which leaked from buried drums and pails
in the former disposal area during 1975 to 1980; in 1980, the drums were
excavated and releases to the area ceased. It appears that additional VOC
releases may have occurred in a southern drum staging area in the vicinity of the
large concrete pad west of the piggery building. These releases were likely the

result of either previous site activities during waste disposal operations or leaks or spillages during the period that EPA handled and staged drums in this area. These areas are shown on Figure 4-1.

Since the drums and pails containing waste material were removed from the site in 1981, the principal source of contamination at the site (i.e., releases of waste from these containers) has been removed from the site. Since that time, the source of contamination in the former disposal area and the southern staging area has been, and at the current time is, contaminants associated with past releases which were released and sorbed onto soil in these areas. Since the removal of the exhumed drums and pails from the Mottolo site by EPA in 1980/1981, these two contaminated soils source areas have been subjected to environmental decay. Primary source area decay mechanisms at the Mottolo site are ground water flow (which dissolves and transports contaminants from the sources area), percolation (which dissolves contaminants and transports them to ground water), and to a lesser extent volatilization (which results in some fraction of VOCs forming a vapor phase in unsaturated soil pore space and ultimately migrating to the atmosphere). Because each of these decay processes result in the reduction of contaminant mass in the source area, both the extent and magnitude of impacts associated with these source areas has declined since removal of the drummed wastes from the site, and will continue to decline in the future.

Based upon soil quality data for the former disposal area, it appears the most highly contaminated soils are in the vicinity of the water table. This dispersive occurrence could be expected with slow releases from leaking drums (as compared to instantaneous releases from ruptured vessels), the sorptive capacity of unsaturated soils, the inability of non-aqueous phase liquids with densities less than water to reside below the capillary surface or water table, the tendency for non-aqueous materials, including dense liquids, to develop pools or lenses on top of the capillary fringe prior to penetrating the capillary surface, and the ability of lateral advective ground water flow to dissolve or transport small breaches of

soluble non-aqueous phase liquids through the water table surface in a relatively rapid manner.

The VOCs identified as present in site soils at concentrations well above detection limits by CLP analyses of soil samples from this area include the chlorinated aliphatic compounds methylene chloride, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene; the aromatic compounds toluene, ethylbenzene, and xylenes; and acetone, a ketone. Some VOCs not detected in the soil samples analyzed and detected at significant concentrations in ground water include vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethene and tetrahydrofuran. However, because releases from the previously buried drums likely resulted in affecting localized areas of soils, it is probable that the density of borings advanced in the former disposal area was not sufficient to identify each affected zone in the area. Additionally, some of the VOCs not observed in soil samples but found in ground water could be the by-products of indigenous microbial degradation of VOCs which are known to be present on site.

The saturated volume of contaminated soils will vary due to seasonal fluctuations which were observed to be as much as 5 feet during the course of the 1989 monitoring program. This fluctuation is currently believed to have a significant affect on the release of contaminants from soils to ground water, the greatest release occurring in the spring when the water table is highest and ground water is in contact with a larger volume of contaminated soils. This occurrence is supported by the analytical data for ground water samples collected from the two overburden monitoring wells located closest to and downgradient of the former disposal area, wells OW-2SR and OW-4SR. These data indicated greater concentrations of total VOCs in ground water samples from these wells in April 1989 as compared to samples collected in September and December. The ground water samples from monitoring well OW-2SR were reported to contain 25,300 ppb, 10,028 ppb and 13,040 ppb total VOCs in April, September and December, respectively; samples from monitoring well OW-4SR were reported to contain 8860 ppb, 1031 ppb and 667 ppb during the same periods. At both

locations, total VOC concentrations were greater in the spring as compared to later in the year.

As discussed in Section 4.0, the source area responsible for the presence of VOCs in ground water in the southern boundary area is believed to be in overburden in the vicinity of the large concrete pad located west of the piggery building. The presumed source of the VOCs in this area is thought to be the result of leaks or spills from drums staged in this area during EPA removal activities. Since VOC concentrations are higher in the bedrock monitoring well MW-8D than in the overburden well MW-8S, it appears that the VOC source is in overburden soils in close proximity to the bedrock surface. Due to the upland location of the concrete pad and the thin layer of overburden in this area, ground water is not present in the overburden in some areas during at least part of the year. During these periods, VOC releases from source area soils would occur as a result of either soil gas migration or surface water infiltration through the soils.

## 5.2 CONTAMINANT MIGRATION PATHWAYS

Potential contaminant migration pathways at the Mottolo site could include overburden ground water flow, bedrock ground water flow, surface water, overland flow, soil gas and ambient air. The significance and combination of pathways varies according to the nature of the source area and site physical characteristics. Accordingly, contaminant migration pathways are discussed below with respect to the two source areas.

### 5.2.1 Former Disposal Area

Contaminants in soils in this area can migrate via several pathways with the significance of the different contaminant migration routes varying seasonally. A conceptual migration pathway flow chart for contamination originating from the former disposal area is shown on Figure 5-1. In the vadose zone, some portion of the VOCs with high vapor pressures are likely to volatilize into soil pore space and

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migrate by diffusion. Some of this mobilized VOC will migrate to the ground surface, at times drawn by atmospheric pressure changes, and discharge to ambient air. In the fall, when the vadose zone is thickest, this migration route is likely more significant than in the spring when the water table and infiltration rates are relatively high. Based upon air monitoring conducted during the RI, this migration pathway is not thought to be significant.

The primary migration pathways resulting in mobilization of contaminants sorbed to soils in the former disposal area are precipitation percolation and advective overburden ground water flow. As previously discussed, these two processes are directly related to seasonal trends. During the spring and early fall, when most precipitation occurs, percolation volumes are greatest, and the water table rises into residually contaminated soils, resulting in larger amounts of dissolution and contaminant transport from unsaturated soils to the water table. During the winter and summer, when percolation volumes are low to negligible, the water table drops and precipitation infiltration and dissolution play a lesser role in the mobilization of contaminants from former disposal area soils.

The significance of temporal advective overburden ground water flow with respect to contaminant mobilization from source area soils is similar to that of percolation. As previously discussed in Section 4.0, and for the reasons presented in Section 5.1, the majority of VOCs detected in soils present within the former disposal area were observed at or near the water table. Thus, during periods when the water table is relatively low (i.e., summer and winter months), there is little to no saturated overburden ground water flow through the most highly-affected soils, and thus, little to no mobilization of these contaminants. During these periods, contaminants continue to be mobilized from the source area but primarily from deeper and less-affected soils. Conversely, during periods with a relatively high water table, ground water flows through the most contaminated soils and mobilizes much larger amounts of the contaminants.

This mobilization process was generally observed during the course of on-site RI ground water sampling and analysis, with the highest overburden ground water VOC concentrations observed in the spring, and lower levels observed during the remainder of the year when the water table was lower. On this basis, precipitation percolation and overburden ground water flow are believed to be the two primary mechanisms responsible for mobilization of contaminants from source area soils.

Once mobilized, contaminants in overburden ground water may migrate through one of three primary processes. The dissolved contaminants can discharge with ground water as seeps, can travel with overburden ground water toward Brook A, or can travel with ground water into bedrock. During the course of the RI, surface water seeps were observed at the toe of the former disposal area, along the drainage swale bed, and at the toe of the western Brook A valley wall. Surface water samples of the on-site drainage swale at Station S-9 did indicate the transport and discharge of VOCs through this pathway. However, measurements of flow in this swale, as well as observations made throughout the course of the RI, indicate that the volume of surface water seeps emanating from the site is relatively small as compared to the volume of ground water flow emanating from beneath the site. As such, this migration pathway was not thought to be significant with respect to the discharge of contaminants to Brook A.

The transport of contaminants in overburden ground water flow toward Brook A, and in overburden ground water flow into upper bedrock, were identified as the two principal migration paths for contaminants mobilized from source area soils. With respect to migration in overburden ground water flow, some of the mobilized contaminants will migrate east-northeasterly with overburden ground water flow toward the on-site swale and then either migrate due east through drainage swale sediments and discharge to swale surface water, or through Brook A valley sediments and to brook surface water. Data collected during the RI indicate that overburden ground water in the upland area west of monitoring well OW-2SR also flows downward into the bedrock, an additional pathway for contaminant

migration. The majority of contaminants entering the bedrock migrate easterly to Brook A with the predominant ground water gradient. Data indicate that east of monitoring well OW-2SR, vertical gradients between the bedrock and the overburden are upward with Brook A being identified as the local ground water discharge zone. Therefore, in the Brook A valley, contaminants will migrate upward with ground water into the overburden, through Brook A sediments, and ultimately to Brook A surface water.

Though it appears that the majority of contaminant migration from the former disposal area is through overburden and bedrock ground water flow to the east toward Brook A based upon the relatively high concentrations reported in ground water along this pathway, data also indicate that lesser amounts of contaminants are migrating with shallow bedrock ground water flow along fractures and joints in a northeasterly direction and discharging to the overburden and Brook A in the vicinity of monitoring well couplet MO-5. One of the predominant fracture and joint orientations identified during the RI was a trend of approximately 45 degrees northeast which is consistent with the regional bedrock structural trend. As contaminants migrate to Brook A driven by the eastward hydraulic gradient, joints are intersected which trend northeast and some contaminated ground water flows along these joints. The higher average total VOC concentration detected in the bedrock monitoring well MO-5DR (98 ppb) as compared to the overburden well MO-5S (16 ppb) during the 1989 monitoring program are consistent with the belief that contaminants detected in overburden in this area originated from contaminated ground water discharging upward from bedrock to overburden.

Since the average total VOC concentration in well MO-2DR, the closest bedrock monitoring well to the south of MO-5DR, is 242 ppb, and nearly vertical upward gradients have been measured along Brook A as shown in Figure 3-18, it appears unlikely that contaminated ground water in bedrock in the area of the drainage swale confluence with Brook A flows significantly northward before discharging to the overburden and Brook A. Therefore, it is likely that the primary pathway for contaminant migration from the former drum disposal area to the vicinity of well

MO-5DR is via a northeasterly pathway in the bedrock. Historical water quality data also support this theory. For instance, samples collected from monitoring wells MO-2D and MO-5D in August 1985 contained 1745 ppb and 702 ppb total VOCs, respectively. Due to the strong upward vertical gradients observed in the Brook A valley, it is unlikely that a large portion of the VOCs present in ground water in the vicinity of well MO-2D could have traveled far north in the valley and contributed significantly to the VOCs reported present in the sample from well MO-5D. Thus, it is likely that the source of these VOCs was from another pathway, that being ground water flow traveling to the northeast from the former disposal area through shallow fractured bedrock. As in the area to the south of the drainage swale, contaminated ground water following this pathway is also expected to ultimately discharge to Brook A.

Data from monitoring well couplets MW-12 and MW-13 indicate only trace or low level ground water contamination in either the overburden or bedrock on the east side of Brook A. When combined with the westerly ground water flow direction identified in the overburden and bedrock east of Brook A, it is expected that contaminants, where identified, in this area would also ultimately migrate to Brook A surface water.

Levels of arsenic have not been identified in Brook A surface water. Thus it appears that arsenic mobilized from the site area and transported by ground water flow is removed from the ground water through sorption onto soil and sediment particles prior to reaching Brook A. This mechanism appears feasible due to the relatively low concentration of arsenic reported present in site ground water, and the low to moderate ground water flow rates estimated for the site.

VOCs in ground water have historically been shown to discharge to Brook A surface water as indicated by surface water quality data collected from Brook A over the last ten years. As discussed in Section 6.0, the half-life of the VOCs in surface water that are discharged to Brook A are relatively short, ranging from a few hours to several days. As shown by surface water quality data collected from

Brook A during the course of the RI, as well as historic data collected during the past ten years, significant VOC concentration reductions have been observed in Brook A as water in the brook flows to the north. The principal loss mechanism for these VOCs is expected to be volatilization due to the shallow, well-mixed nature of Brook A, and the localized areas of turbulent or cascading flow present in the brook due to presence of large rocks or other obstruction in the brook channel. Ground water discharge to Brook A from other portions of the study area may also serve to dilute the VOCs discharged to Brook A from the Mottolo site, although this dilution process is not believed to be significant in terms of the VOC concentrations observed in Brook A surface water because VOC concentrations have historically been reduced to non-detectable levels within a short distance downstream of the site drainage swale and Brook A confluence.

## 5.2.2    Southern Boundary Area

Potential contaminant migration pathways for the southern boundary area are somewhat more limited than those for the former disposal area as shown on Figure 5-1. This is due to the absence of observed ground water seeps in close proximity to the southern boundary area, and the likelihood that during some portions of the year, the affected soils which serve as the VOC source for the area are unsaturated. Furthermore, the role of overburden ground water flow as it relates to contaminant transport is believed to be much less. Notwithstanding these differences, there are many similarities between the nature of contaminant pathways for this area as compared to the former disposal area.

As with the former disposal area, contaminants present in the southern boundary area are expected to be mobilized by overburden ground water flow or precipitation infiltration. Once mobilized, they are believed to either travel with overburden ground water, or during portions of the year, directly enter shallow bedrock with the percolating water. VOCs migrating with overburden ground water flow appear to laterally travel only a short distance before entering shallow bedrock ground water. These pathways are consistent with data obtained during the RI indicating

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that the overburden is relatively thin on all but the southern side of the large concrete pad west of the piggery building and that the water table is not present in portions of the overburden during at least portions of the year. Since low levels of VOCs were detected in samples from monitoring well MW-8S, some VOCs are known to be migrating with overburden ground water flow. However, since VOCs were not reported present in ground water samples collected from either downgradient overburden monitoring wells MW-20S or MW-21S, the extent of VOC migration in the overburden is thought to be limited. Once in the bedrock, the VOCs are expected to flow with the bedrock ground water to the south-southwest for several hundred feet where, based upon the Brook A drainage basin flow model presented in Section 3.0, the migration pathway in expected to turn to the south-southeast. At this point, unless adsorbed during the transport process, VOCs would discharge with bedrock ground water to saturated overburden soils and ultimately to the headwater area for Brook A. However, upon reaching surface water in the headwaters to Brook A, the concentrations of VOCs in surface water would likely be at non-detectable levels due to dispersive dilution of the VOCs which occurs during advective transport.

## 5.3     CONTAMINANT TRANSPORT

Primary constituents of concern identified in ground water and surface water include chlorinated aliphatic compounds, aromatic hydrocarbons, tetrahydrofuran, and arsenic. Total VOC concentrations observed in surface water during the RI ranged between below detection limits (BDL) and approximately 41 ppb while arsenic was not reported above detection limits. Total VOC concentrations reported in ground water ranged from BDL to 25,300 ppb and arsenic concentrations ranged from BDL to 570 ppb. Total VOC concentrations reported in sediment samples ranged from BDL to 534 ppb and arsenic concentrations range from BDL to 80.7 ppm.

Based upon the discussion presented in Section 5.2, the contaminants described above are transported through two primary pathways at the Mottolo site, those

being ground water and surface water. The discussion below addresses processes deemed to be significant to contaminant transport at the Mottolo site within these two primary pathways.

### 5.3.1    Contaminant Transport In Ground Water

**Overburden**

Overburden ground water flow rates estimated using data obtained during the RI in the upland area west of well OW-2SR, between well OW-2SR and the western base of the Brook A valley wall, and between the western base of the Brook A valley wall and Brook A, ranged from approximately 66 to 440 feet per year (fpy), 170 to 840 fpy, and 33 to 220 fpy, respectively. Bedrock ground water flow rates were estimated to range from 17 to 417 feet per day. In the southern boundary area, overburden and upper bedrock ground water is expected to flow south-southeast toward the wetland and marsh area associated with the headwaters of Brook A at flow rates similar to those calculated above.

Mass transfer processes most affecting contaminant transport at the Mottolo site include ground water advection and, to a lesser extent, longitudinal dispersion. Advection refers to the bulk transport of dissolved contaminants by ground water at a rate approximated by the average ground water flow rate. During the advection process, hydrodynamic dispersion of contaminants present in ground water typically occurs, resulting in enlargement of the contaminant plume. Hydrodynamic dispersion can be divided into two primary processes. The first, termed mechanical dispersion, is best described on a microscopic scale; however, its results are observable on a macroscopic scale. Mechanical dispersion involves spreading of a contaminant plume due to mechanical mixing of dissolved contaminants during advective flow. This mixing occurs due to variations in pore geometry and changes in flow directions that deviate from the mean ground water flow direction. Longitudinal dispersion, one component of hydrodynamic dispersion, results in the movement of ground water and dissolved contaminants

at rates faster and slower than the average ground water flow rate. This causes spreading of the contaminant plume along the longitudinal axis of the plume in the general ground water flow direction and results in a decrease in contaminant concentration. Prior studies have shown that hydrodynamic dispersion is scale dependent and that it is proportional to the ground water flow rate.

The second process contributing to hydrodynamic dispersion is a microscopic process termed molecular diffusion. Molecular diffusion is observed through the movement of contaminants from areas of high concentration toward areas of lower concentration along concentration gradients, and tends to be less than mechanical dispersion in most ground water flow systems unless very low ground water flow rates are present such as in low permeability materials.

In general, ground water flow rates in overburden at the site are relatively moderate, suggesting that mechanical dispersion is more significant than molecular diffusion in affecting contaminant transport. The role dispersion plays in affecting contaminant transport from the former disposal area at the Mottolo site appears to be related to geographic location. In the upland portion of the site, overburden ground water velocities are moderately fast, allowing for some dispersion of contaminants in the ground water. However, after ground water reaches sediments underlying the swale between the upland area and the base of the Brook A valley wall, the existence of the bedrock trough appears to limit further lateral dispersion of the contaminant plume. Once contaminants in ground water enter the Brook A valley, much more dispersion appears to occur, perhaps in part due to discharge of ground water from bedrock to overburden. This is reflected in the broadening of the VOC plume in Brook A valley and the reduction of average VOC concentrations observed in ground water from the top of the valley wall (16,100 ppb in well OW-2SR) to the floor of the valley (259 ppb in well MO-2S and 797 ppb in well MO-3SR), both shown in Figure 4-16. This dispersive process occurs simultaneously with easterly advective flow, resulting in concurrent spreading of the plume while the plume migrates toward and ultimately discharges to Brook A.

With respect to VOC transport from the southern boundary area in overburden ground water, dispersion is believed to play a minor role due to the short travel distance before the VOCs enter bedrock ground water, leaving advection to be the primary transport mechanism.

Chemical mass transfer processes most affecting contaminant transport in ground water at the Mottolo site include dissolution and sorption/desorption. In order for contaminants to enter the aqueous phase, dissolution must occur. This is a common chemical mass transfer mechanism which results when water with lower dissolved concentrations of constituents flows through media with greater relative constituent concentrations. Dissolution does not affect the mass of constituents in a system as it only serves to transfer a portion of the constituent mass from one phase to another, although it will result in a reduction in the constituent mass in the source area if no further mass is added to the source area, which is the case for both the former disposal area and the southern boundary area at the Mottolo site.

Sorption refers to the process through which dissolved constituents partition from the aqueous phase (ground water) onto a solid phase (soil particles) encountered during ground water flow. To a large extent, sorption of organic chemicals occurs as a function of the fraction of organic carbon present in the soil matrix. Soil particle size, shape and charge can also play a role in sorption. Desorption is the opposite process of sorption whereby chemicals bound to a solid phase will solubilize, although the desorption process generally occurs at a slower rate than sorption. The sorption process does not affect the mass of a constituent, but does retard or attenuate constituent transport. For non-polar organic contaminants, sorption/desorption process is often treated as an equilibrium process between the aqueous phase and the soil matrix. As discussed previously, sorption of contaminants onto residually affected soils has occurred at the Mottolo site. The occurrence of this mass transfer via desorption/sorption is evidenced by a comparison of the extent of aromatic hydrocarbon contamination in ground water with chlorinated aliphatic hydrocarbons. The greatest concentrations of aromatic

hydrocarbons were generally observed in the overburden ground water between the former disposal area and the top of the Brook A valley wall. Although the greatest concentrations of chlorinated aliphatic hydrocarbons were also found in this same area, the proportional reduction in concentration of these VOCs in Brook A valley monitoring wells was much less than that for aromatic VOCs, indicating much greater retardation, and thus sorption, of the aromatic compounds. Furthermore, aromatic VOCs were not observed in Brook A surface water samples during the course of the RI, whereas chlorinated aliphatic hydrocarbons were observed. This is likely due to the relatively low solubilities and high partitioning coefficients of the aromatic VOCs which results in relatively greater sorption and less mobilization of these compounds as compared to the chlorinated aliphatic compounds.

As discussed previously in Section 5.1, due to the length of time since the EPA response action, it is likely that desorptive processes are presently occurring across the site in both source area soils and residually affected soils. Since shortly after completion of the EPA 1980/1981 response action, this natural flushing process has been occurring with advection, dispersion and desorption being the primary processes affecting contaminant transport at the site. Additional evidence for the occurrence of this process is exhibited by a comparison of historic ground water quality analytical data collected between 1980 and 1989. Historical water quality data are presented in Appendix A-1. The general trend of these data is that contaminant concentrations have decreased in surface and ground water throughout the site over this period. A comparison made of the six most affected well couplets demonstrates the significant levels of total VOC reduction observed in site ground water between 1980 and 1989. The two OW-series couplets, OW-2 and OW-4, are located very near the former disposal area and were originally installed in 1980. The four MO-series couplets, MO-2, MO-3, MO-4 and MO-5, are spread across the site and were originally installed in 1985. Total VOC levels in wells MO-2S and MO-2D have dropped from 5,300 ppb and 2,070 ppb to averages of 259 ppb and 684 ppb, respectively. Total VOC levels in wells MO-3S and MO-3D have dropped from 5,700 ppb and 1,750 ppb to averages of 780 ppb and

550 ppb, respectively. In well MO-4S, total VOC levels have declined from 35 ppb to an average of 12 ppb, with only trace and non-detectable levels being observed in well MO-4D. In wells MO-5S and MO-5D, total VOC levels have fallen from 113 ppb and 912 ppb to average levels of 16 ppb and 98 ppb, respectively. Total VOC concentrations in well OW-2D fell from a high of 125,000 ppb to an average of 2,868 between 1980 and 1989. Insufficient data were available for well OW-4D to identify a trend.

These VOC concentration reduction factors of between three and twenty clearly show that impacts from the Mottolo site have declined with time, and should continue to do so in the future in the absence of any site action. Additionally, these data also show that because no further contaminants have been disposed of on the Mottolo site since at least 1980, and because ground water flow has been reducing the contaminant mass in the source areas through dissolution and advection, both the size of and impacts from the two identified contaminant source areas have both declined since 1980. Some apparent anomalies were identified in this trend in the two overburden OW-series wells, OW-2S and OW-4S. These trend variations were attributed to the reinstallation of these two wells during the RI, and the likelihood that they are now monitoring somewhat different zones than the wells they replaced. However, a closer examination of these data also indicate the occurrence of a similar contaminant concentration reduction trend. For well OW-2S, total VOC concentrations between 1980 and 1985 fell from a maximum of 34,200 ppb, with several other values in 1980 ranging from 7,600 ppb to 15,200 ppb, to a low in 1985 of 204 ppb, with some other values in 1985 as high as 3,526 ppb. After reinstallation, the average total VOC concentration in well OW-2SR was approximately 16,000 ppb. For well OW-4S, total VOC concentrations between 1980 and 1985 fell from an average of 50,700 ppb to an average of 3,640 ppb. After reinstallation, the average total VOC level in well OW-4SR was approximately 3,500 ppb. Thus, upon closer examination, data from these wells also indicate sizeable decay or mass reduction of the principal contaminant source area on the Mottolo site.

Because these data demonstrate the past improvement of ground water quality at the Mottolo site with time, and because the unit masses of contaminants emanating from the on-site source areas are declining with time, it is highly likely that average annual contaminant concentrations in site ground water will continue to decline with time, as well as the resultant concentrations in Brook A.

**Bedrock**

The same processes which govern contaminant transport in overburden can generally be applied to bedrock. Advection is also expected to be a dominant transport process in bedrock at the Mottolo site since field data suggest that bedrock in the site area is moderately fractured. Based upon this information, mechanical dispersion is also considered to be the dominant dispersive process. However, advection is expected to be the dominant contaminant transport mechanism in bedrock due to the nature of flow through fractured media and the limited area for sorption/desorption to occur within this media. This may be evidenced by the larger relative extent of VOCs observed in bedrock ground water as compared to overburden ground water as shown in Figures 4-16, and 4-17. Since bedrock at the Mottolo site has essentially no primary porosity, contaminant pathways in this unit are expected to be along preferential flow zones associated with fractures and joints. As previously discussed, this in part explains the concentrations of VOCs detected in the bedrock in the area of couplet MO-5. However, the majority of ground water flow and associated contaminant transport in bedrock is expected to be east toward Brook A as indicated by the much greater concentrations of VOCs reported in the area of the swale confluence with Brook A. In addition, the types of VOCs which have been observed in monitoring well couplet MO-5 have higher relative solubilities (e.g., 1,1-DCA solibility limit is 5,500 mg/l at 20°C; 1,2-DCE is 3,500-6,300 mg/l at 20°C; TCE is 1,100 mg/l at 25°C and THF which is fully miscible), would tend to migrate relatively further and be less susceptible to attenuation during advection in overburden and bedrock than the aromatic VOCs not reported present in well couplet MO-5 but present at elevated levels in wells in close proximity to the former disposal area. (e.g.,

ethylbenzene solubility limit is 152 mg/l at 20°C; toluene is 515 mg/l at 20°C and xylenes is 130 to 198 mg/l at 25°C).

### 5.3.2    Contaminant Transport In Surface Water

The mechanisms of contaminant transport to surface water present on the Mottolo site have been discussed in Sections 5.1 and 5.2. In summary, advective ground flow through overburden is believed to be the primary contaminant transport mechanism. Once in surface water, contaminants may be transported with the surface water, they may sorb onto channel sediments, or, if volatile, they may be released to ambient air. Contaminants which do sorb onto channel bottom particles are also subject to desorption as clean surface water flows over them. This sorption/desorption process is evidenced by the VOCs observed in sediments at Stations S-2 and S-3, both located near the confluence of the swale and Brook A. The low VOC concentrations in these sediments and the limited extent of VOCs in Brook A sediments are likely due to the sorption process discussed above which occurs within the relatively narrow area corresponding to dissolved VOC and ground water discharge through the Brook A bed, and the desorption process which continually occurs due to passage of clean, upstream water over the VOC-affected sediment. VOCs being transported in surface water are subject to higher relative advective flow rates and more aeration, both of which promote volatilization.

Therefore, in the drainage swale and Brook A, advection is the dominant contaminant transport process. However, based upon the relatively low volume of flow in the swale, the mass of contaminants transported in swale surface water is not expected to be significant when compared to the contaminant mass transported in ground water to Brook A. In addition to advection in Brook A, mechanical mixing in the brook may be significant since aeration of the water occurs readily in many locations where riffle zones and turbulent eddies are present.

## 5.4    CONTAMINANT FATE

As previously discussed, contaminants mobilized from the two source areas identified on the Mottolo site are expected to migrate to Brook A principally through ground water and, to a minor extent, through surface water. Arsenic, the only non-volatile constituent of concern identified at the Mottolo site, has not been reported present at detectable levels in Brook A surface water, likely due to its sorption into soil particles and dilution during transport with ground water. VOCs have been observed in surface water in close proximity to the confluence of the swale and Brook A, but are expected to volatilize from the brook within relatively short distances downstream. Surface water quality data collected during the RI indicates that the VOCs detected in surface water in the vicinity of the drainage swale confluence with Brook A, the location where ground water with the highest levels of VOCs discharges to Brook A, were not reported present in surface water samples collected 400 feet downstream of this area. The levels of VOCs discharging to ambient air from Brook A are considered to be insignificant due to the low concentrations of VOCs in Brook A, and because VOCs were not reported in ambient air above background levels during monitoring conducted throughout the course of RI field activities.

## 5.5    SUMMARY

The initial release of contaminants in the former disposal area was most likely the result of leaks from buried drums and pails in this area from 1975 to 1980. The source of contamination in the southern boundary area in the area of the large concrete pad is most likely spills or leaks that occurred either during previous waste disposal activities or from drums staged during EPA removal activities. Contaminants from the former disposal area are expected to migrate along two pathways which are similar to the general ground water flow directions observed on site. Currently, the primary flow path is from overburden, downward through the upper bedrock west of approximately well OW-2SR, then upward from the bedrock to the overburden east of well OW-2SR, and ultimately discharging to

Brook A. Some contaminants that enter the bedrock may deviate from the predominantly easterly flow direction and migrate more toward the northeast via fractures that are oriented in this direction. The second flow path is in saturated overburden to Brook A. Contaminants from the southern boundary area are believed to leave the Mottolo site principally in shallow bedrock ground water, and flow with this water generally to the south before discharging to the headwaters of Brook A.

The nature and extent of contamination observed in environm tal media at the Mottolo site and the data reviewed during the RI indicate that advection, dispersion and sorption/desorption are the primary processes affecting contaminant transport; other attenuation processes are believed to play a minor role. As a result, the direction and rate of contaminant migration is assumed to be controlled primarily by ground water flow patterns in the overburden and bedrock. Brook A, the local ground water discharge feature, is the most significant receptor of contaminants which remain mobile in ground water. Surface water samples collected in Brook A during the RI indicate that the VOCs discharging to the brook via the swale and ground water volatilize to ambient air within 400 feet downstream of the brook confluence with the swale.

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Section 6

# 6.0 BASELINE RISK ASSESSMENT

The Mottolo Site Baseline Risk Assessment (MBRA) is performed in conjunction with the Mottolo Site Remedial Investigation/Feasibility Study (RI/FS) as required under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Superfund Amendments and Reauthorization Act (SARA). The process provides for the assessment of potential threats to public health and the environment for sites that have been placed on the National Priorities List (NPL).

The primary focus of the MBRA is to assess baseline conditions at the site and to evaluate potential risks to human health and the environment in the absence of remediation. The risk assessment process draws on information provided from site topography and geology, site history, field activities, analytical results, screening data, and other sources. Within this framework, the risk assessment serves to identify hazards associated with the site, select specific contaminants of concern, judge the toxicological or carcinogenic significance of these contaminants, assess scenarios of exposure pathways, and characterize potential risks. Information developed within the risk assessment is to be used for assessing remedial actions to reduce risks at the site associated with past waste disposal activities, but is not intended to fully characterize site risks.

The MBRA has been prepared in three sections. The first section consists of the Hazard and Dose-Response Assessment, the second section focuses on the Exposure Assessment, and the third section integrates sections one and two to provide the Risk Characterization, and contains the Endangerment Assessment. Methods of risk evaluation are based upon the EPA documents, "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual" (HHEM), "Supplemental Risk Assessment Guidance for the Superfund Program, EPA Region I" (SRA), and "Superfund Public Health Evaluation Manual" (SPHEM).

## 6.1    HAZARD IDENTIFICATION AND DOSE-RESPONSE ASSESSMENT

In the Hazard Identification and Dose-Response Assessment, compounds associated with the site which may pose the most risk to human health and the environment are identified. The rationale for selecting these indicator compounds is detailed along with dose-response data necessary for calculating exposure doses associated with specific exposure pathways as defined in the Exposure Assessment.

### 6.1.1    Site Background

The Mottolo site area is part of the Mottolo property. The property occupies roughly 50 acres of rolling hills and woods surrounded by a developing residential community in Raymond, New Hampshire. Much of Mottolo property is thickly wooded, although trees have been cleared in a portion of the site area. A steeply banked brook, Brook A, flows north through the eastern side of the Mottolo property and empties into the Exeter River. A drainage swale flows intermittently into Brook A. The Mottolo study area includes the adjacent residential community and undeveloped property. Approximate boundaries and the relationship of the Mottolo site area to the Mottolo study area are shown in Figure 1-1.

The Mottolo property was originally the site of a piggery, and the remains of on-site buildings and foundations still exist. In the late 1970's, a small area of the property was discovered to be the location of a hazardous waste disposal operation. During an EPA drum removal operation in 1981, over 1600 55-gallon drums and 5-gallon pails in various conditions were staged, overpacked as necessary, and removed from a 0.25 acre portion of the Mottolo property, now referred to as the former drum disposal area. Prominent site features of the Mottolo property are shown in Figure 1-3.

Since the EPA drum removal, a major concern has been the potential impact of contaminants on local ground water and, specifically, the residential wells which are located in the vicinity of the Mottolo site area. In addition, contaminated soil has been detected in, and adjacent to, the former drum disposal area. The drainage swale flows intermittently through an area adjacent to the former drum disposal area into Brook A.

Access to the Mottolo property is restricted by the surrounding undeveloped, forest and "no trespassing" signs are prominently posted; however, entry to the property can be gained by foot. Vehicular access to the Mottolo property is controlled by a locked gate.

## 6.1.2   Sampling and Analysis Program

The sampling and analysis program at the Mottolo Site involved both qualitative and quantitative sampling of potentially contaminated media including ground water, surface water, sediments, soil, soil gas, and air. Representative samples were collected based upon known or suspected areas of contaminant impact, site history, and sampling data collected by previous investigators. Particular attention was given to sensitive off-site locations and upgradient locations in an attempt to determine the concentrations and the types of contaminants present and the extent of contamination in each environmental medium. Sampling programs were approved by EPA prior to the conduct of each sampling activity.

One major focus of the sampling and analysis program was to assess current conditions in ground water. Ground water sampling rounds were performed in April, September, and December of 1989 to address the possibility of seasonal ground water differences in contaminant concentrations. A supplemental ground water sampling round was performed in March 1990. A total of 40 monitoring wells installed in the overburden and bedrock were sampled during the program. The sampling locations included monitoring wells within the former drum disposal

area, along the drainage swale, south of the piggery, along Brook A, and in residential areas adjacent to the site.

In conjunction with the Mottolo RI/FS, ground water samples were also collected by New Hampshire Department of Environmental Services (NHDES) from a total of 23 private residential wells within the study area. Sampling of ground water from private residential wells was performed concurrently with the Mottolo RI/FS sampling rounds in April, September, and December of 1989.

Surface water samples were collected from locations upgradient from potential source areas in the on-site drainage swale and Brook A, downgradient of the former drum disposal area within Brook A and the Exeter River, and within the swale drainage area. Surface water samples were collected at approximately the same sampling stations for each of the three sampling rounds in April, September, and December of 1989 to address possible seasonal variations in contaminant concentrations.

Sediment samples were collected in April 1989 from the on-site drainage swale and Brook A at the same locations surface water samples were collected to allow assessment of contaminant concentrations in this medium both upgradient of and downgradient from the former drum disposal area.

The extent of on-site soil and ground water contamination was assessed by first performing a soil gas survey in the area around the former drum disposal area to approximate boundaries of the area. The survey was then extended to encompass the remainder of the Mottolo property to evaluate the extent of volatile organic compound (VOC) migration in ground water, as well as the presence of other possible sources of VOCs.

Soil borings were used to further describe the areal and vertical extent of soil contamination associated with the former drum disposal area, and to investigate

potential soil contamination in former drum staging areas. Soil boring samples were selected for submittal to an analytical laboratory based upon field screening results and in-house gas chromatograph screening analyses. Depths at which samples were collected varied; however, saturated and unsaturated conditions were represented among the samples submitted for analysis. Analytical laboratory data provided quantitative results and compound confirmation, while screening data provided qualitative results and an indication of the depth of contamination.

An air monitoring survey was performed at the Mottolo Site in October 1988 to assess the levels of VOCs present in ambient air throughout the site area, as well as in close proximity to the former drum disposal area. Concentrations of VOCs in ambient air were not detected during this survey, which was consistent with the results of former on-site air quality monitoring. In accordance with the Mottolo Project Operations Plan (POP), the establishment of a quantitative, long-term air monitoring program was therefore not warranted. Air quality monitoring was similarly performed during intrusive on-site work, some of which involved the disturbance of site soils within the former drum disposal area. VOC concentrations were not detected above background levels in ambient air, and therefore did not exceed the 15 parts per million (ppm) action level established in the Mottolo POP for these field activities. This provided confirmation that a long-term air monitoring program was not necessary. Ambient air quality monitoring was performed using an HNu PI-101 photoionization detector and/or Foxboro Model OVA-128 flame ionization detector.

### 6.1.3    Analytical Parameters

The selection of parameters to be analyzed for each environmental medium was based largely on discussions with EPA and NHDES. In general, samples collected during the initial sampling round for the specific environmental medium were analyzed for a comprehensive suite of parameters including the full Hazardous Substance List (HSL) compounds as well as other site-specific compounds. The

analytical suite for subsequent sampling rounds focused on specific compounds based on results from the initial sampling round. The selection of analyses for the later sampling rounds was developed with, and approved by, EPA and NHDES.

In the first comprehensive ground water sampling round, samples were analyzed for the HSL VOCs plus tetrahydrofuran (THF) and methyl tert-butyl ether (MTBE), HSL Semivolatile or Acid/Base Neutral Extractable Organic Compounds (ABNs), HSL Pesticides/PCBs, HSL inorganic substances plus cyanide, microbiological parameters, and a variety of general water quality indicator parameters. Analytical parameters for the second round focused on HSL VOCs, THF and arsenic; selected locations were also analyzed for HSL ABNs, HSL Pesticides/PCBs, and HSL inorganic substances plus cyanide. The third ground water sampling round included only analyses for HSL VOCs, THF, and arsenic.

Surface water samples collected during the first comprehensive sampling round were analyzed for parameters similar to the first round ground water samples, except that analyses for microbiological parameters were not performed. Subsequent surface water analyses focused on HSL VOCs, THF and Pesticides/PCBs in the second sampling round, and HSL VOCs and THF in the third sampling round.

Sediment sample analyses included HSL VOCs, THF, MTBE, HSL ABNs, HSL Pesticides/PCBs, and HSL inorganic substances plus cyanide.

Soil samples selected from the initial phase of the site boring program were submitted for analysis of HSL VOCs, THF, and MTBE: additional analyses included HSL ABNs, HSL Pesticides/PCBs, and HSL inorganic substances plus cyanide. Soil samples selected from the second phase of the site boring program were analyzed for HSL VOCs, THF, MTBE, and lead.

### 6.1.4 Database Used for Risk Evaluation

**Data Reporting and Data Validation**

Analytical data for organic compounds and inorganic substances used in the risk determination were subjected to an internal validation review consistent with provisions in the Mottolo POP and the EPA guidance documents, "Laboratory Data Validation, Functional Guidelines For Evaluating Organics Analyses" and "Laboratory Data Validation, Functional Guidelines For Evaluating Inorganics Analyses." Data qualification actions as a result of the validation reviews included the adjustment of sample detection limits for analytes reported in associated blank samples and the flagging of results as estimated concentrations due to failures in meeting various quality control criteria.

**Computation of Contaminant Frequencies and Concentration Ranges**

Ranges of concentrations for detected compounds were compiled for ground water, surface water, sediment, and soil samples and included the lowest and the maximum concentration detected within the three sampling rounds. The frequency of detection for each compound detected was also compiled based on the number of times detected relative to the total number of analyses for that parameter. The total number of sample analyses included those for field duplicate samples.

**Computation of Mean Concentrations**

The use of either arithmetic or geometric means for presenting mean concentrations of compounds selected for detailed evaluation is suggested when evaluating an entire site or discrete areas of a site (USEPA, 1989b). Various methods of compiling mean statistics were considered for the MBRA.

Sampling locations and monitoring wells were located to either intercept or delineate boundaries of contaminated media and, therefore, present a set of data biased toward showing contaminant impact. It was determined that the arithmetic mean statistic would be a conservative, but representative, estimate of the mean contaminant concentration for each medium and each area of contamination.

Ground water data mean statistics for potentially contaminated areas were calculated by first obtaining a mean concentration for each selected indicator compound over the three sampling rounds. This provided a representative mean value for each location over time and represented the average annual exposure concentration to be used in the Exposure Assessment. In cases where samples were not analyzed for all parameters in each of the three sampling rounds, the mean for the location was based upon available data. The average of field duplicate samples was computed prior to obtaining the location mean to limit skewing of the data. The mean of the location means was then computed for selected contaminated areas. Mean concentrations for selected compounds in various environmental media are presented in the Exposure Assessment.

**Evaluation of Non-Detected Results**

As acknowledged in the SRA guidance, analytical results reported by the laboratory as not detected do not necessarily indicate the compound is not present in the sampled medium. Sample detection limits may have been raised by the laboratory as a result of sample dilution required for high compound concentrations or as a result of matrix interferences. Similarly, the data validation review may have resulted in the adjustment of detection limits for sample compounds reported as detected in a sample and in associated laboratory method blank, trip blank, or field blank samples. In either case, specific analytes may be present in the sample, but may be reported as not detected because of an elevated detection limit.

In order to account for the possibility that compounds were present at concentrations less than the detection limit, mean calculations involving non-detected results were calculated using a value of one-half the sample detection limit for the non-detected analyte. For analytes with adjusted detection limits as a result of the validation review, the value of one-half the sample detection limit prior to adjustment of the detection limit was used. The following detection limits were used in the laboratory reported data: Contract Required Detection Limit (CRDL) or method detection limit (MDL) for organic compound analyses, and the instrument detection limit (IDL) or MDL for analyses of inorganic substances.

It is noted in the HHEM that non-detected sample results with high detection limits can skew concentration means if the compound has been detected in other samples at low concentrations (USEPA, 1989a). Therefore, the method presented in the HHEM was used to limit overestimating the mean concentration as a result of elevated detection limits. The mean for each designated sample set was computed including one-half the detection limit for non-detected results. If this mean concentration was greater than the highest concentration for that compound detected in the sample set, then the data with the elevated detection limit was not included in the calculation.

## 6.1.5    Extent of Contamination

Areas of the site in which contaminants were detected were identified for purposes of assessing the risk associated with each area and each medium. Sampling locations for each medium were grouped according to contaminant type, relative concentration, and proximity of sampling locations to develop a profile of each contaminated area. Outlying sampling locations with negligible levels of contamination were excluded from this evaluation, but have been considered in the evaluation of fate and transport in Section 5.0. A more detailed discussion and breakdown of contaminant characteristics for defined areas of contamination is provided in Section 4.0. Concentration ranges and locations of the maximum

concentrations for ground water and surface water samples are shown in Table 4-1, and for soil and sediment samples are shown in Table 4-2.

**Ground Water**

The main area of ground water contamination is located on the Mottolo Site and included the following monitoring wells: OW-2SR, OW-2DR, OW-4SR, OW-4DR, MO-2S, MO-2DR, MO-3SR, MO-3DR, MO-4S, MO-4D, MO-5S, and MO-5D. Monitoring wells OW-3R and MW-11D had significantly lower levels of contamination but were included within this area of ground water contamination because of their close proximity to the former drum staging area and the former drum disposal area. This area is designated as Area 1 on Figure 6-1.

In Area 1, a total of fourteen HSL VOCs, thirteen HSL ABNs, and six HSL Pesticide/PCBs were detected in ground water. The maximum concentration for each VOC was detected downgradient of the former drum disposal area in overburden monitoring wells OW-2SR or OW-4SR, or in bedrock monitoring wells OW-2DR and OW-4DR. Concentrations ranged up to 9200 parts per billion (ppb) for a single compound. Primary VOCs present included vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethene (total of cis- and trans- isomers), 1,1,1-trichloroethane, toluene, ethylbenzene, xylene, and tetrahydrofuran. ABNs were detected at significantly lower concentrations than VOCs; the maximum concentration detected for an ABN compound was 130 ppb (approximate concentration) for 2-methylphenol. The maximum concentrations reported for several inorganic substances were also detected at these locations.

Much lower VOC concentrations and negligible levels of ABNs (total concentrations of 15 ppb or less) and Pesticides/PCBs (not detected) were reported in samples collected from monitoring wells at the toe of the slope along Brook A and at the base of the drainage swale. Monitoring wells within this portion of Area 1 included MO-2S, MO-2DR, MO-3SR, MO-3DR, MO-4S, MO-4D, MO-5S, and

MO-5D. Concentrations reported for most inorganic substances were similar to background levels. Arsenic was reported as present at several on-site and off-site wells, and may be naturally occurring. A maximum concentration of 570 ppb was reported as present in a sample from monitoring well MO-3SR.

Aroclor 1260 was reported present at concentrations less than the CRDL in two ground water samples collected from Area 1 monitoring wells. The reported Aroclor was most likely due to the introduction of this compound at the analytical laboratory rather than an indication of its presence in ground water samples collected from these wells.

A second area of ground water contamination included monitoring wells MW-8S, MW-8D, MW-20S, MW-20D, MW-21S, and MW-21D. These monitoring wells were grouped and evaluated separately because of their location in an area hydraulically distinct from Area 1 wells, because of the much smaller subset and differing nature of contaminants reported to be present in samples from these wells, and because of their close proximity to one another. This area is designated as Area 2 in Figure 6-1. VOCs were not detected in samples collected from wells MW-20S, MW-20D, and MW-21S; however, VOCs were reported present in samples collected from wells MW-21D, MW-8S, and MW-8D. The maximum concentrations for trichloroethene at 1,100 ppb and tetrahydrofuran at 47 ppb were reported in samples collected from well MW-21D. The maximum concentration of 1,2-dichloroethene (total) at 110 ppb was detected in a sample from well MW-8D. Arsenic levels in ground water samples from Area 2 were much less than those observed in some Area 1 monitoring wells.

The presence of individual VOC concentrations greater than 2 ppb was not indicated in the residential well samples collected from private residences within the study area and analyzed by NHDES. Trace quantities of VOCs (total of 0.52 ppb to 4.65 ppb) were reported in one sample collected during each of three

sampling rounds conducted by NHDES during the RI, although these VOCs were not directly attributed to releases from the Mottolo site.

## Surface Water

Surface water samples collected from sampling stations S-3, S-5, and S-9 were reported to contain detectable levels of a total of 8 different VOCs. Station S-9 was located in the on-site drainage swale adjacent to the former drum disposal area, while stations S-3 and S-5 were located in Brook A. Concentrations detected were typically at or near the limits of reliable quantitation for most compounds; however, the compound 1,1-dichloroethene was an exception, and was reported present at a concentration of 41 ppb in a sample collected from station S-9.

Low levels of bis(2-ethylhexyl)phthalate were reported in samples collected at two locations. Aroclor 1260 was identified at concentrations below the CRDL in the first sampling round; however, the compound was not detected at the same sampling stations in the subsequent rounds. Further review of these data indicated the reported presence of Aroclor 1260 in the first round surface water samples was most likely due to the introduction of this compound into these samples at the analytical laboratory, and tha⁺ Aroclor 1260 was not present in site surface water.

The maximum lead and iron concentrations for surface water were reported in samples collected from sampling station S-9, with concentrations of 13.4 ppb and 3,650 ppb, respectively. Chromium was detected at 12 ppb in a sample collected from station S-10.

## Sediment

VOCs were detected at 5 of the 8 sediment sampling locations, although generally at low concentrations. A total of seven VOCs were detected including acetone,

1,1-dichloroethane, 1,2-dichloroethene (total), 1,1,1-trichloroethane, trichloroethene, toluene, and total xylenes. The variety and concentration of VOCs was greatest in the sample collected from station S-2, where 1,1-dichloroethene was reported to be present at an estimated concentration of 360 ppb. Acetone was reported in a sample collected at station S-10, downslope from and east of the piggery waste pile.

Inorganic substances analyzed at the upgradient sediment sampling location S-10 represented the maximum reported concentrations in the medium for aluminum, arsenic, barium, cadmium, calcium, cobalt, iron, lead, magnesium, manganese, sodium, vanadium, and zinc. Concentrations for arsenic, barium, calcium, and iron were in excess of ten times greater than levels encountered at other background locations S-4 and S-1. Arsenic was detected at a concentration of 60.7 ppm at location S-10, with levels decreasing progressively at downstream locations to background levels at station S-6 on the northern edge of the Mottolo property border.

**Soil**

VOCs were the primary compounds detected within the area of the former drum disposal area. Among the thirteen VOC and eight ABN compounds reported as present in soil boring samples, ethylbenzene, toluene, and total xylenes had the highest concentrations at 140 ppm, 470 ppm and 270 ppm, respectively. Total VOC concentrations exceeding 21 ppm were detected in 4 of 19 samples, although concentrations were generally much lower in the other soil samples. ABN concentrations were highest for bis(2-ethylhexyl)phthalate at a maximum level of 1.3 ppm. Among the 19 soil samples analyzed for lead, reported concentrations in 15 samples were less than 27 ppm. Lead concentrations in excess of 100 ppm were reported in only four soil samples.

### 6.1.6    Indicator Compounds

Compounds were selected as contaminants of concern to focus the Hazard Identification and Dose-Response Assessment on the substances most likely to pose a risk to human health and the environment. Site contaminants were evaluated in terms of toxicity, carcinogenicity, concentration, media in which they were detected, frequency of detection, and location. A hierarchy was established to screen out compounds of relatively low toxicity and carcinogenicity, compounds detected infrequently and at low concentrations, compounds detected at concentrations significantly less than established Maximum Contaminant Levels (MCLs), National Primary Drinking Water Regulations (NPDWRs) or New Hampshire Division of Public Health Services (NHDPHS) drinking water health standards, and compounds detected at or near background levels. The persistence or mobility of the compound was also considered prior to eliminating a compound from further evaluation as an indicator compound.

Indicator compounds were selected for ground water, surface water, soil, and sediment media. Tables 6-1 through 6-4 summarize the screening process and rationale for selection of indicator compounds for each environmental medium.

Initial screening of indicator compounds was performed using data and methodology presented in SPHEM, in which compound concentrations were multiplied by screening toxicity constants to provide an indicator score (USEPA, 1986). Indicator scores were calculated, where applicable, and compounds were ranked to provide an indication of their relative carcinogenicity, and then ranked separately to provide an indication of relative toxicity. Some compounds have the potential of producing carcinogenic and noncarcinogenic effects; therefore, some substances were evaluated under both categories.

Compounds detected between one and three times in the more than 100 ground water samples and at low concentrations were not considered significant site contaminants and were omitted from further evaluation.

Compounds present at concentrations less than MCLs or NPDWRs as listed in USEPA (1990a), or NHDPHS criteria, were also not considered to be present at significant levels. This screening method was most applicable for inorganic substances and xylenes in ground water samples. MCLs, NPDWRs and NHDPHS criteria used for this purpose are summarized in Table 6-5, while other applicable or relevant and appropriate requirements (ARARs) are summarized in the Mottolo FS report.

Background concentrations of compounds in upgradient locations were compared to downgradient locations as a further means of selecting indicator compounds. This was particularly useful for evaluating inorganic substances which occur naturally.

Total xylenes were excluded from the list of indicator compounds for the aqueous media based on a review of MCLs. The maximum total xylene concentration of 4,700 ppb reported as present in a ground water sample from one well was well below the proposed MCL of 10,000 ppb. It should be noted that this action level of 10,000 ppb is the same value also proposed as a Maximum Contaminant Level Goal (MCLG), which is based on health risk. In addition, the maximum reported concentration for total xylenes was far in excess of total xylene concentrations reported as present in other aqueous samples; therefore, reported concentrations in these samples were even further below the proposed MCL.

Lead was excluded from the list of indicator compounds for the soil and sediment media after careful evaluation. Lead was reported at moderate concentrations in a few of the soil boring samples, but was reported at low concentrations in the remainder of the samples. It was concluded that lead was not present at sufficient concentrations or at a high enough frequency to warrant attention as an indicator

compound. The maximum concentration of 181 ppm reported in one soil boring sample was well below the interim soil cleanup level of 500 to 1000 ppm recently established by EPA for CERCLA sites (Longest, 1989). Moreover, in establishing this level, EPA used a conservative approach by considering the possibility of exposure by children and indicating that this level be followed when the current or predicted future land use is residential.

A total of ten different contaminants of concern were selected for the Mottolo Site. Among these, the following nine indicator compounds were selected for the ground water medium: arsenic; 1,1-dichloroethane; 1,2-dichloroethene (total); ethylbenzene; trichloroethene; 1,1,1-trichloroethane; tetrahydrofuran; toluene; and vinyl chloride. Two indicator compounds, 1,1-dichloroethane and 1,2-dichloroethene (total), were selected for the surface water medium. Two indicator compounds, 1,1-dichloroethane and 1,1,1-trichloroethane, were selected for the sediment medium. Three indicator compounds were selected for the soil medium including ethylbenzene, toluene, and total xylenes.

### 6.1.7    Dose-Response Assessment

The dose-response section of the MBRA provides the scientific data relating chemical exposure (dose) to potential health effects (response). Specific information is provided to evaluate the dose-response relationships for indicator compounds.

The reference dose (RfD) is used as the primary criterion for evaluating non-carcinogenic effects. In using this value, it is assumed that there is a concentration which serves as the threshold at which no critical adverse effects exist. This level is referred to as the "no observed-adverse health effects level" (NOAEL). The following hierarchy of threshold values is suggested in the SRA guidance in the event RfDs have not been established by EPA: Drinking Water Equivalent Levels (DWEL), Lifetime Health Advisories and Maximum

Contaminant Level Goals (MCLG), and Acceptable Intake Chronic (AIC) and Ambient Water Quality Criteria (AWQC).

It is the EPA CERCLA risk assessment policy that carcinogens lack a threshold of no adverse effects, which thus implies that any concentration carries some risk. However, cancer potency factors (CPFs) have been derived which estimate risks based upon extrapolation at various doses. A CPF is equal to the slope of the dose-response curve. When multiplied by the dose, this provides an estimate of the upper 95 percent confidence interval (i.e, the upper conservative limit) of the incremental lifetime cancer risk, or probability of causing cancer above normal background rates.

Carcinogens have been rated by EPA in a weight-of-evidence classification system to indicate the degree of confidence in the relationship between chemical exposure and the likelihood of causing human cancer. Ratings are based primarily on the degree of evidence for cancer from human and animal studies. Major categories include: A, human carcinogen; B1, probable human carcinogen with limited evidence for carcinogenicity in humans; B2, probable human carcinogen with sufficient evidence of carcinogenicity in animals and inadequate or lack of evidence in humans; C, possible human carcinogen; D, not classified; and E, no evidence of carcinogenicity to humans.

The RfD values, CPF values, and other pertinent dose-response data for the selected indicator compounds are shown in Table 6-6. Based on discussions with EPA Region I, oral RfDs were not calculated for selected indicator compounds classified by EPA as carcinogenic or potentially carcinogenic and lacking EPA-verified RfDs. Calculations of dose-response values for compounds not listed in Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST) are provided in the appropriate toxicological summary.

**Toxicological Summaries for Indicator Compounds**

This section provides general information and a brief toxicological summary for the selected indicator compounds. A toxicity assessment is included whereby carcinogenic and noncarcinogenic effects of the indicator compounds are considered. Where available, information has been derived from the IRIS data base, as of March 1990. More detailed toxicological information for each indicator compound is presented in Appendix C-8.

Arsenic

Arsenic, like most inorganic substances, is naturally occurring in soil and sediments (USEPA, 1987). Toxicological effects of arsenic are highly dependent on the medium in which it occurs, the form which it takes (organic or inorganic), and its ionic state (trivalent or pentavalent). Organic forms of arsenic are much less toxic than inorganic forms, with trivalent inorganic arsenicals being much more toxic than pentavalent forms (USEPA, 1987). The form of arsenic in water is influenced by pH, suspended solids, organic content, and presence of sediment (USEPA, 1987). The half-life of arsenic in air is established as 5.0 days and in surface water the substance is considered more persistent (USEPA, 1986).

Acute exposure due to ingestion of arsenic may result in changes in skin pigmentation, chronic headache, fatigue, muscle weakness, insomnia and gastritis, while chronic exposures to ingested arsenic have been shown to cause skin lesions, peripheral vascular disease, and neural degeneration (USEPA, 1984a). The function of bone marrow appears to be particularly impaired upon chronic exposure. Liver and kidney damage have been reported in laboratory rats upon oral exposure to arsenic (USEPA, 1984a).

Arsenic has been classified by EPA as a human carcinogen (Class A). An increased incidence of lung cancer in humans has been observed upon inhalation

(IRIS, 1990). Increases in the incidence of skin cancer upon ingestion of high arsenic concentrations in drinking water have also been reported. The EPA Administrator recommends that the unit risk of 5E-05/ug/l, derived from a drinking water study, be adopted (IRIS, 1990). A CPF can be calculated from this unit risk using the following equation:

CPF = (UR x W)/(CR x CF)

Where UR = unit risk (in /ug/l); CR = consumption rate of 2 l/day;
CF = conversion factor of $10^{-3}$; and W = adult weight of 70 kg.

CPF = (5E-05/ug/l X 70kg)/(2 l/day x $10^{-3}$)
CPF = 1.8E+00 $(mg/kg/day)^{-1}$

This calculated CPF for arsenic reflects use of the upper 95 percent confidence limit of the water unit risk, and as such provides a very conservative (high safety factor) estimate of the CPF. Furthermore, the unit risk used in estimating this CPF assumed all the arsenic ingested was inorganic (the more toxic form) in nature. In recommending use of this unit risk to calculate a CPF, the EPA Administrator cautions that uncertainties associated with the use of this value may result in overestimations of risk by as much as an order of magnitude, even without consideration of the fraction of arsenic which may be organic in form.

1,1-Dichloroethane

The compound 1,1-dichloroethane is a halogenated aliphatic hydrocarbon. Evaporation is expected to be the primary loss mechanism from surface soils (USEPA 1984b). The half-life in surface water is between 1.0 and 5.0 days (USEPA, 1986).

Information is not available to indicate unusual human sensitivities to the compound (USEPA, 1984b). Chronic effects of inhalation may include symptoms of digestive irritation and central nervous system depression, while ingestion may cause drowsiness, unconsciousness, or liver damage (NIOSH, 1985). The compound has recently been classified by EPA as a possible human carcinogen (Class C) (USEPA 1990b). A CPF of 9.1E-02 $(mg/kg/day)^{-1}$ has been established by EPA (USEPA, 1990b). No information was provided in the source document describing the reliability of this CPF.

1,2-Dichloroethene (total)

This compound is a halogenated aliphatic hydrocarbon which occurs in trans- or cis- isomers. Release into the environment results in the rapid evaporation from surface soil or surface water (USEPA, 1987). The half-life in surface water is between 1.0 and 6.0 days (USEPA, 1986).

Exposure to high concentrations may cause nausea, vomiting, and weakness; however, recovery is often prompt following removal from the exposure source (Olishifski and McElroy, 1971). According to EPA, the compound is unclassifiable as a human carcinogen (Class D). The compound is often evaluated in terms of the trans- isomer because of a larger knowledge base; however, confidence in the oral RfD of 2.0E-02 mg/kg/day is low because of lack of chronic studies or studies on developmental or reproductive toxicology (IRIS, 1990).

Ethylbenzene

Ethylbenzene is a monocyclic aromatic hydrocarbon which is extremely volatile when present in surface media. The half-life in surface water is between 1.5 and 7.5 days (USEPA, 1986).

Inhalation of high concentrations may cause irritation of the eyes and mucous membranes, and may lead to dizziness (GRI, 1988). Ethylbenzene is readily absorbed after exposure by inhalation, oral intake or dermal contact, and toxic effects have been observed via each route (GRI, 1988). In humans, toxicity has generally been characterized in terms of skin irritation (IRIS, 1990).

Ethylbenzene has not been classified by EPA as to carcinogenicity (Class D) due to lack of animal bioassays or human studies (IRIS, 1990). Confidence in the established oral RfD of 1.0E-01 mg/kg/day is low because the primary study for estimating the value used rats of only one sex, and the study was not long-term (IRIS, 1990).

Tetrahydrofuran

Tetrahydrofuran is a heterocyclic hydrocarbon. Little information is available on the environmental fate of the compound.

Chronic responses in inhalation studies have included nausea, dizziness, and headache (Olishifski and McElroy, 1971). While the liver appears to be a target organ, liver damage has not been observed in humans (Hurst, 1990). Liver effects and stomach inflammation have been reported in some animal studies (Hurst, 1990).

The compound has not been evaluated or classified in regard to carcinogenicity, and no verified RfDs or water quality standards have been developed by EPA. A provisional oral RfD of 2.0E-03 mg/kg/day has been calculated by the EPA Environmental Criteria and Assessment Office (ECAO), which will be seeking further review of this value (Hurst, 1990). However, confidence in the provisional RfD is low, as indicated by an uncertainty factor of 10,000 applied to the NOAEL of 22 mg/kg/day (Hurst, 1990).

## Toluene

Toluene is a monocyclic aromatic hydrocarbon which is highly volatile. The half-life in surface water is 0.17 days (USEPA, 1986).

Toluene is readily absorbed after inhalation, dermal or oral exposure (GRI, 1988). Acute exposures may cause depression of the central nervous system, respiratory irritation, impaired balance, or nausea (GRI, 1988). Following uptake into the body, toluene becomes distributed according to locations of highest lipid content such as adipose tissue and bone marrow (GRI, 1988).

Toluene is not classified according to carcinogenicity (Class D) because of lack of human data and inadequate animal data. Positive results for carcinogenicity have not been observed in the majority of bioassays (IRIS, 1990). Confidence in the established oral RfD of 3.0E-01 mg/kg/day is medium because it is based primarily on one inhalation study; however, the study was well-designed and is supported by several other studies (IRIS, 1990).

## 1,1,1-Trichloroethane

The compound 1,1,1-trichloroethane is a halogenated aliphatic hydrocarbon with a half-life in surface water of between 0.14 and 7.0 days (USEPA, 1986).

Generally regarded as one of the least toxic of the chlorinated hydrocarbons, chronic exposure effects focus on the disruption of the central nervous system (Olishifski and McElroy, 1971).

The compound is not classifiable as a human carcinogen (Class D). Based on the few studies performed, there is no evidence to demonstrate carcinogenicity in humans or animals (IRIS, 1990). Confidence in the established oral RfD of

9.0E-02 mg/kg/day is considered by EPA to be medium to low because of a comprehensive, but inconsistent database (IRIS, 1990).

## Trichloroethene

Trichloroethene is halogenated aliphatic hydrocarbon which volatilizes rapidly upon exposure to air. The half-life in surface water is between 1.0 and 90.0 days (USEPA, 1986).

The compound has been shown to affect the nervous system when inhaled in high concentrations and may result in headache, dizziness, or slow reflexes (NIOSH, 1985). Chronic exposure may lead to anorexia, nausea, and vomiting (NIOSH, 1985).

Trichloroethene has been classified by EPA as a probable human carcinogen (Class B2), based on limited evidence. The carcinogenicity assessment for this chemical is currently under EPA review, and an oral RfD and CPF are not presented in IRIS (IRIS, 1990). A CPF of 1.1E-02 $(mg/kg/day)^{-1}$, established by EPA, is reported in HEAST (USEPA 1990b).

## Vinyl Chloride

Vinyl chloride is an extremely volatile aliphatic hydrocarbon. The half-life in surface water is between 1.0 and 5.0 days (USEPA, 1986). Despite a low soil sorption rate, there is a low probability that vinyl chloride will leach from soil into ground water (USEPA, 1984c). The compound may sometimes appear as a degradation product of trichloroethene or tetrachloroethene.

Inhalation of high concentrations may cause tissue necrosis (USEPA, 1984c). Chronic exposure via oral or inhalation routes may cause an increased incidence of liver, lung, or brain tumors (USEPA, 1984c).

According to EPA, sufficient evidence exists to classify the compound as a human carcinogen (Class A). A CPF of 2.3E-02 (mg/kg/day)$^{-1}$ has been established by EPA and is reported in HEAST (USEPA, 1990b).

Total Xylenes

Xylenes (ortho-, para-, and meta- isomers) are a group of monocyclic aromatic hydrocarbons capable of rapid volatilization from surface water and surface soil (GRI, 1988). The half-life in surface water is between 1.0 and 9.0 days (USEPA, 1986). In aquatic environments, small quantities of xylene may become adsorbed to organic matter or sediments (GRI, 1988).

Xylene is apparently absorbed by humans and animals following inhalation or ingestion, since toxicities typically correspond to these routes of exposure (GRI, 1988). Inhalation appears to be the more toxic route of exposure for humans with high concentrations causing central nervous system depression or changes in blood chemistry (GRI, 1988).

Xylenes are not classified by EPA as to human carcinogenicity (Class D). Orally administered doses of technical grade xylene mixtures have not produced a significant increase in tumors for rats or mice (IRIS, 1990). Confidence in the established oral RfD of 2.0E+00 mg/kg/day is medium, with much supportive evidence based on the oral route of exposure for a large group of animals over a large portion of their lifespan (IRIS, 1990).

## 6.2    EXPOSURE ASSESSMENT

The Exposure Assessment is performed to identify major exposure pathways and the routes by which compounds reported as present at the site may reach potential receptors in the absence of site remediation. Within the Exposure Assessment, potential exposure points are identified, exposure concentrations are calculated,

and exposure doses are estimated for the selected indicator compounds for use in the Risk Characterization.

## 6.2.1    Exposure Setting

The exposure setting represents the arena in which a potential exposure to compounds may occur.  In evaluating the exposure setting relative to the Mottolo site, various environmental media were considered as potential sources of exposure to the selected indicator compounds.  Compound concentrations reported for samples collected from the various environmental media have been discussed previously in the Hazard Identification and Dose-Response Assessment.

Ground water is often a primary focus in assessing exposure.  In the vicinity of the Mottolo site, ground water derived from residential bedrock wells is currently used as a drinking water source.  Other uses of ground water within the study area have not been identified.  Drinking water wells are not presently installed on the Mottolo site or within the Mottolo property.

Surface water and sediments are other important media through which exposure may occur.  Surface water bodies in the vicinity of the Mottolo site consist of the Exeter River which flows through the northeast corner of the study area, the brooks, the drainageways and the associated wetlands.  Surface water bodies on the Mottolo site include Brook A and, at times, the drainage swale which passes adjacent to the former drum disposal area and former drum staging area.

Potential exposure to surface and/or subsurface soils are generally considered important pathways.  At the Mottolo site, the primary focus for exposure to compounds in soil concerns a small portion of the Mottolo site near the former drum disposal area.  Furthermore, unlike many other Superfund sites, the vast majority of wastes disposed of at the Mottolo site have long been removed from the site; this removal was undertaken by EPA in 1980-1981 and involved the

exhumation and off-site disposal of approximately 1,600 drums and containers, as well as approximately 160 cubic yards of contaminated soil and debris. Thus, only remaining residually-affected soils are believed to be acting as the current contaminant source on the site.

At some sites, the release of compounds into the air as vapors or particulates may serve as a source of exposure. At the Mottolo site this is not considered to be an important exposure pathway.

EPA guidance suggests that the emphasis on exposure be placed on the most sensitive populations with a potential for exposure (USEPA, 1989a; USEPA, 1989b). Sensitive populations can include infants, children, and the elderly; it is therefore important to consider nursing homes, hospitals, and schools located within study area. Facilities of this type have not been identified in the immediate vicinity of the Mottolo site. For this reason, emphasis was placed on children and those populations in closest proximity to the site.

The nature and extent of potential exposure for segments of these populations will be evaluated further. Much of this discussion concerns the probability of exposure, particularly by children. The Mottolo property is not currently developed or easily accessible for recreation. It is posted with "no trespassing" signs and is secured with a locked gate, although trespassers can enter the site by foot. Given the nature of the site, it is unlikely that young children of age five or less would enter the site area, due to the distance from the nearest private residences. Trash and empty bottles left at the site suggest that trespassing by older children or adults occasionally occurs.

## 6.2.2    Evaluation of General Exposure Pathways

Potential exposure pathways were evaluated for contaminated media to determine which pathways were most relevant to the site and which pathways represented

the greatest potential health risks. EPA defines an exposure pathway as having each of the following elements (USEPA, 1986):

o   a source and release mechanism for the compounds into the environment,

o   an environmental transport mechanism for the compounds and/or a mechanism by which the compounds may be transferred from one medium to another,

o   an exposure point at which there is a potential for contact with the contaminated medium by a receptor, and

o   an exposure route at the exposure point.

VOCs and some inorganic substances have been reported as present in on-site ground water, surface water, sediments and soils. Various ingestion and direct contact exposure pathways were considered pertinent to the risk evaluation for on-site and off-site use under current and future conditions. A summary of the evaluated exposure pathways is shown in Table 6-7.

**Current Use**

Ground Water

The ingestion of compounds in drinking water derived from ground water sources can be a major pathway of concern. Currently, there are no on-site private wells at the Mottolo property. Ground water from off-site residential bedrock wells is consumed within the study area. Low levels of VOCs have occasionally been reported present in samples collected by the NHDES from a few of these residential bedrock wells; however, there is little evidence that these VOCs are related to the Mottolo site. Furthermore, monitoring of ground water quality in overburden and bedrock monitoring wells conducted as part of the RI has not shown significant levels of VOCs (i.e., greater than an estimated concentration of 4 ppb) to be present in off-site wells. The Mottolo Site RI has shown that ground water migrating in overburden and bedrock, and beneath the former drum

disposal area and drum staging area, generally flows to the east and discharges to Brook A. There are currently no water supply wells located between these areas and Brook A. For these reasons, current use of ground water was therefore not evaluated as an exposure pathway.

Surface Water

The possibility of dermal contact with on-site surface water and incidental ingestion of surface water by children is feasible and thus, was considered. Brook A is a small body of water, shallow enough to preclude such activities as swimming, yet sufficient in size to serve as a place for wading. It is less likely that persons wading in the brook would ingest water; however, children wading in the brook may be more prone to this activity. In the winter months, from December to March, Brook A has in the past been covered with a layer of ice several inches thick, thus limiting contact with surface water. The drainage swale adjacent to the former drum disposal area is an intermittent surface water discharge which flows during wetter periods of the year, but is dry or reduced to a trickle in mid-summer. In the winter months from December to March, the drainage swale is frozen, eliminating the potential for dermal contact with surface water. As such, it represents a possible point of exposure during limited times of the year.

VOCs and inorganic substances were reported at or near background concentrations in off-site surface water samples collected from Brook A, and other downstream sampling stations in the Exeter River. Potential exposure to contaminated surface water at off-site locations is therefore unlikely.

Sediment

The possibility of dermal contact with and incidental ingestion of on-site sediments by children was considered. Contacting contaminated on-site sediments in

Brook A when wading is possible. As with surface water exposure, the incidental ingestion of contaminated sediments represents an unlikely yet plausible scenario for children.

As with the surface water data, the presence of VOCs or inorganic substances in off-site sediment samples from Brook A was reported at background concentrations. The potential for exposure to contaminated off-site sediments is therefore unlikely.

<u>Soil</u>

Exposure to compounds in surficial soil was not considered a likely pathway under current site conditions and was therefore not evaluated. The presence of significant concentrations (i.e., greater than trace levels) of VOCs have not been reported in on-site surface soils (i.e., zero to six inches below ground surface) based upon data reported from the VOC headspace screening program and supported by laboratory analytical data. In addition, the VOCs selected as indicator compounds have been shown to volatilize rapidly from soil surfaces (USEPA, 1986).

Dermal contact with and incidental ingestion of subsurface soils by children and adults was evaluated. In order to contact on-site contaminated soils under present conditions, people entering the site would have to dig within the former drum disposal area, a small portion of the site. Older children on rare occasion may perform such an activity. Analysis of subsurface soil boring samples collected from the former drum disposal area and former drum staging area indicate that the distribution of VOCs is not homogeneous, indicating that exposure to site contaminants may or may not occur during this activity.

## Air

Particulate and vapor inhalation exposure scenarios were not considered likely under present conditions at either on-site or off-site locations based on the results of on-site ambient air monitoring performed during the course of the RI.

## Ingestion of Fish

Consumption of contaminated fish was not considered a potential on-site exposure pathway because Brook A is not large or deep enough to support recreational fishing, and because edible fish were not observed on-site in Brook A during the course of the RI.

For potential off-site exposure pathways, consideration was given to bioaccumulation of compounds which may occur when organisms present at lower ends of the food chain in Brook A (e.g., invertebrates) are consumed by edible fish in the Exeter River. However, there are several reasons why this represents an unlikely exposure pathway. The compounds of concern at the Mottolo site are not among the compounds most apt to bioaccumulate (IRIS, 1990; CHRIS, 1985). Moreover, sample results were reported at non-detectable or background concentrations for off-site, downstream surface water and sediment sampling stations in Brook A and the Exeter River. It is also unlikely that fish caught in the Exeter River rely heavily on Brook A for a supply of invertebrate prey species as there are other brooks in the vicinity which flow into the Exeter River.

## Future Use

## Ground Water

Residential development of the Mottolo site is a possible future scenario. Exposure pathways for future ground water use are highly dependent on the exact location

of the private well installation. As a consequence, the potential for ingestion, dermal contact or inhalation of vapors during household use was addressed independently for ground water from different on-site areas, for off-site areas to the south of the Mottolo property, and for off-site areas to the north, east and west of the Mottolo property.

The group of on-site monitoring wells designated within Area 1 are located near the former drum disposal area, the former drum staging and storage areas, and along the drainage swale to the bottom of the slope in the Brook A valley. Residential wells, if installed on the Mottolo site within Area 1, could present an exposure pathway for compounds now reported as detected in these monitoring wells. The areal extent of affected ground water has been shown to be confined to this limited area. Ground water indicator compound concentrations will decrease in the future over time as the residual compounds within the source area dissipate. Therefore, future life-time exposure concentrations are likely to be significantly less than current concentrations.

A group of monitoring wells designated within Area 2 straddles the southern border of the Mottolo property. Future residential development to the south of Area 2, and concurrent development of domestic supply wells, is feasible. Residential wells, if installed on the Mottolo site within Area 2, or immediately south of Area 2, could present an exposure pathway for compounds now reported as detected in the Area 2 monitoring wells. For the same reasons described above, indicator compound concentrations are likely to decrease with time as residual contamination in the source area dissipates.

Private wells installed within most other areas of the site would not be expected to present a significant exposure pathway, as compound concentrations for samples collected from most of these wells are reported as non-detected or are comparable to background levels. Ground water quality monitoring performed to date by the NHDES has not indicated VOC migration from the Mottolo site to developed areas

west, north or east of the Mottolo site. Because regional ground water flow patterns are relatively well understood for the study area, and because the VOC source areas on the Mottolo site are dissipating with time, current and/or future residential wells installed off the Mottolo property in these areas are not expected to be significantly impacted in the future by compounds migrating from the site. More comprehensive discussion of study area ground water flow and contaminant migration has been presented in Sections 3.0 and 5.0, respectively.

Surface Water

Potential dermal exposure to surface water and incidental ingestion was evaluated. Based on potential residential development occurring near the Brook A valley, future on-site exposure to surface water is unlikely to be different than present exposure except for a potential increase in the frequency of exposure due to greater accessibility. Those persons most likely to be exposed via this pathway would be from within a newly (future) constructed residential area in close proximity to the Mottolo site. Future off-site uses of surface water are likely to be similar to current conditions with no potential for significant exposure.

Sediment

Potential exposure to sediments and incidental ingestion were evaluated. As with surface water, future on-site exposures are unlikely to be greatly different than the present potential for exposure, except that the number of children wading in Brook A may increase. This selected exposure pathway focused on younger and older children. Future off-site exposure is likely to be similar to present conditions with less likelihood of exposure.

## Soil

Surficial soils at the Mottolo site were not considered an important future exposure pathway because of the low levels of VOCs reported as present in soil samples collected from within zero to six inches below the ground surface at 16 soil boring locations, based upon the soil VOC headspace screening program and supporting results for surficial soil samples submitted to the analytical laboratory for analysis. In addition, the VOCs selected as indicator compounds for the soil medium are known to volatilize rapidly from soil surfaces (USEPA, 1986).

Dermal contact and incidental ingestion of on-site subsurface soil was evaluated as an exposure pathway, since development of the site could involve the excavation of potentially contaminated soils, thereby moving deeper soils closer to or to the ground surface. Upon development of the area, an exposure pathway may exist for children or adults who dig in the soil. However, the dose for such an exposure would be expected to decline with time due to VOC evaporation from surface and near surface soils, and the tendency for surface water percolation to remove indicator compounds from site soils. Activities which would involve large amounts of soil exposure, such as gardening, would also entail significant soil aeration; VOC exposure from such activities would be higher at the onset and then decline rapidly (e.g., less than five years) thereafter.

## Air

Particulate and vapor inhalation exposure scenarios were not considered important exposure pathways under future conditions at on-site or off-site locations. Potential development of the site would likely result in short-term disturbance and aeration of soils. In turn, because the potential for generation of vapors or particulates would occur over a short time frame, potential frequency of exposure to vapors or particulates would be low.

### 6.2.3 Estimation of Exposure Point Concentrations for Indicator Compounds

Arithmetic mean concentrations of indicator compounds were calculated using methodology described in the Hazard and Dose-Response Assessment to obtain an average exposure point concentration and a maximum plausible exposure point concentration for the indicator compounds associated with each environmental medium. The maximum concentration detected for each indicator compound was also used as an exposure point concentration to provide an extremely conservative, and therefore very unlikely, upperbound value for exposure dose. These estimates provided a basis for evaluating the degree of risk under average to extremely conservative conditions. Average, maximum plausible, and maximum detected exposure point concentrations are summarized in Table 6-8, and are further discussed below.

**Ground Water**

Ground water exposure point concentrations were calculated for the established monitoring well groupings referred to as Area 1 and Area 2. The future exposure points were considered to be located within the approximate boundaries of these groups as shown in Figure 6-1.

Consideration was also given to the ground water quality data base to be used in calculating exposure point concentrations for the ground water exposure scenario. This issue was raised and evaluated based on the hydrogeology present at the Mottolo site. As previously discussed in Section 3.0, a relatively thin veneer of overburden, generally from five to fifteen feet in depth, is present at the site with only some fraction of the overburden being saturated; at some locations, no saturated overburden exists. The silt content and moderate hydraulic conductivity of the overburden do not lend themselves to use of saturated overburden as a water supply aquifer. Bedrock underlying the overburden can serve as a usable

aquifer if wells are drilled to a sufficient depth; the average depth of domestic bedrock water supply wells in the Blueberry Hill Subdivision is 225 feet. Based upon this information regarding site hydrogeology and current ground water use profiles, it was concluded that future use of ground water through the installation of new wells would be similar in nature to current use, that being the installation of wells screened in the bedrock and not the overburden. Although potential future wells will probably be installed into rock to depths exceeding 200 feet, as compared to 15 feet for on-site monitoring wells, and significant VOC concentration dilution would be expected in such wells, no consideration was given to dilution in calculating exposure point concentrations for ground water derived from bedrock; lack of application of a dilution factor will result in overestimating the likely exposure point concentration and thus provides a conservative basis for these calculations. Exposure point concentrations were obtained and evaluated separately for ground water derived from bedrock and ground water derived from overburden.

Mean concentrations were calculated for indicator compounds from Area 1 and Area 2 monitoring wells to provide an average exposure point concentration for potential domestic wells or hypothetical overburden wells installed on-site at a future time within Area 1, or in and south of Area 2. It was judged that these values would represent a conservative estimate because of the bias involved when grouping monitoring wells in which compound concentrations were generally highest. Area 1 ground water concentrations in bedrock were based on monitoring wells MO-2D, MO-3DR, MO-4D, MO-5D, MW-11D, OW-2DR, OW-3R, and OW-4DR; concentrations in the overburden were based on monitoring wells MO-2S, MO-3SR, MO-4S, MO-5S, OW-2SR, and OW-4SR; concentrations in the overburden were based on monitoring wells MO-2S, MO-3SR, MO-4S, MO-5S, OW-2SR, and

OW-4SR. Area 2 ground water concentrations in bedrock were based on monitoring wells MW-8D, MW-20D, and MW-21D; concentrations in the overburden were based on monitoring wells MW-8S, MW-20S, and MW-21S.

The maximum plausible exposure point concentrations for potential bedrock wells or hypothetical overburden wells which may be installed at a future time on-site within Area 1 or within or south of Area 2 were calculated using the average of the maximum indicator compound concentration values observed during all RI ground water monitoring for each well within the two areas. This method was selected to represent the maximum plausible exposure point concentrations because it conservatively reflects the maximum compound concentrations observed in all of the bedrock or overburden monitoring wells within an area, as well as providing some consideration of temporal and spatial variability.

In accordance with EPA Region I policy, the maximum detected concentrations of selected indicator compounds were also used as exposure point concentrations for ground water.

**Surface Water**

Mean concentrations of indicator compounds reported in samples collected from the on-site swale and from stations immediately downstream of the confluence of the swale and Brook A were used to calculate average case exposure point concentrations. Mean statistics for surface water samples were calculated based upon data from the following sample stations: S-2, S-3, S-5, S-6, S-9, and S-10. Upgradient sampling stations (S-1 and S-4) and sampling stations within the Exeter River (S-7 and S-8) were not included. Exclusion of data from these four surface water sampling stations provided a more conservative basis for these calculations. Maximum plausible case exposure point concentrations for surface water were calculated in a manner similar to that for ground water by averaging the maximum indicator compound concentration values observed during all RI

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surface water sampling for each of the six previously identified surface water sampling stations. The maximum concentration detected for each indicator compound was used as an extremely conservative exposure point concentration.

**Sediment**

As with the surface water exposure point calculations, it was judged that the mean concentration for indicator compounds in downstream sediment sampling locations would best represent the average exposure point concentration. The average exposure point concentrations for sediments were calculated using sediment quality data from the same sampling stations used to evaluate surface water, those being stations S-2, S-3, S-5, S-6, S-9, and S-10. Maximum plausible case exposure point concentrations for sediments were based upon the highest concentration reported for each indicator compound observed at any of the six sediment sampling stations, and therefore were the same concentrations used for the maximum detected exposure point concentrations.

**Soil**

The estimate of exposure point concentrations for subsurface soils used a different approach than that used for other media because of the highly biased sampling strategy employed to characterize site soil quality. As previously discussed in Sections 2.0 and 4.0, the purpose of site soil sampling was to delineate the nature and limits of soil contamination; it was not to describe soil quality across the site. Rather, soil sampling was performed in a biased manner to indicate areas known to be contaminated, and was then expanded radially to delineate the extent of contamination. Subsurface soil samples were specifically collected from varying depths, with both saturated and unsaturated conditions being represented. However, further characterization bias was introduced through the bases used to select soil samples for laboratory analysis. In soil borings where variable field VOC screening results were observed in samples from one boring, the sample with

the highest VOC field screening result was generally selected and submitted for laboratory analysis.

Mean exposure point concentrations for soils were calculated by averaging the indicator compound concentrations for each of the nineteen soil samples collected from within or around the former drum disposal area during the soil boring program. The maximum plausible case exposure point concentration for soils was developed with some consideration of the high-side bias included in the site soil sampling program. As previously discussed, many of the soil samples submitted for laboratory analysis were selected based on the results of higher VOC field screening data and thus tended to show higher reported VOC levels. Nevertheless, of the nineteen soil samples submitted for laboratory analyses, only four were reported to contain more than 1.0 ppm total VOCs. The reported VOC concentrations in these four samples were quite different and much higher than the levels reported in the other fifteen samples. Thus, the arithmetic average of the indicator compound concentration from these four soil samples were judged to be reflective of the maximum plausible soil exposure point concentrations. The maximum detected concentrations for each indicator compound were used as extremely conservative, maximum detected exposure point concentrations.

### 6.2.4　Estimation of Exposure Doses for Selected Exposure Pathways

Exposure doses were calculated for each selected indicator compound for an environmental medium and for each selected exposure pathway. Current and future exposure scenarios were considered. Estimates of exposure dose were derived using exposure point concentrations from Section 6.2.3. These estimates will serve as the basis for, and will be evaluated collectively in, the Risk Characterization.

**Current Use**

<u>Dermal Contact With and Incidental Ingestion of Soil</u>

Exposure to soil at the Mottolo site via dermal contact was judged to be a possible scenario. In addition, exposure may result from inadvertent ingestion of soil adhering to the hands. Presently, in order to be exposed to indicator compounds present in soil, a person must dig into subsurface soils. Persons likely to be performing these activities would be older children who may trespass on the site.

The following assumptions were made in the calculation of exposure doses. An average body weight of 30 kilograms was assumed as the weight of a typical child between six and fifteen years of age. Because the digging activity necessary to contact contaminated soils would involve some effort, the frequency of occurrence was not likely to be very high. Although no evidence of digging in the former drum disposal area was observed during the course of the RI, an average occurrence of five times per year and a maximum plausible occurrence rate of ten times per year were assumed over a duration of 10 years. The soil contact rate (500 mg/day) for dermal scenarios, soil ingestion rate (100 mg/day) for ingestion scenarios involving older children and adults, and relative absorption factors were derived by EPA as a means of providing consistency to the estimation of exposure doses (USEPA, 1989b). These and other assumptions are summarized in Table 6-9 along with exposure doses calculated for the exposure pathway.

The equation below was used to estimate exposure doses for dermal contact with contaminated soil (USEPA, 1989b):

$$EXP_{sa} = \frac{CS \times CF \times SCR \times EF \times ED \times RAF}{BW \times AVG \times Y}$$

where:

$EXP_{sa}$ = Average daily absorbed exposure dose (mg/kg/day)
CS   = Compound concentration in soil (mg/kg)
CF   = Conversion factor ($10^{-6}$ kg/mg)
SCR  = Soil contact rate (mg/day)
EF   = Frequency of exposure (days/year)
ED   = Duration of exposure (years)
RAF  = Relative dermal absorption factor (unitless)
BW   = Body weight (kg)
AVG  = Number of years over which exposure is averaged
       (70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y    = 365 days/year

The equation below was used to estimate exposure doses for incidental ingestion of contaminated soil (1989b):

$$EXP_{si} = \frac{CS \times IR \times CF \times EF \times ED \times RAF}{BW \times AVG \times Y}$$

where:

$EXP_{si}$ = Average daily ingestion exposure dose (mg/kg/day)
CS   = Compound concentration in soil (mg/kg)
IR   = Ingestion rate (mg/day)
CF   = Conversion factor ($10^{-6}$ kg/mg)
EF   = Frequency of exposure (days/year)
ED   = Duration of exposure (years)
RAF  = Relative gastric absorption factor (unitless)
BW   = Body weight (kg)
AVG  = Number of years over which exposure is averaged
       (70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y    = 365 days/year

Dermal Contact With and Incidental Ingestion of Surface Water

Wading within Brook A or walking in the drainage swale were judged to be plausible exposure scenarios. However, the potential for incidental ingestion of water from either stream is relatively unlikely, particularly for the extremely low

flows observed in the drainage swale. Nevertheless, incidental ingestion of some surface water was assumed in this exposure scenario. As with the soil exposure scenarios, older children are most likely to perform these activities.

An average body weight of 30 kilograms was assumed as the weight of a typical child, aged six to fifteen (USEPA, 1988a). The mean frequency of exposure was assumed to be 10 times per year while the maximum plausible and maximum calculated frequency of exposure was assumed to be 25 times per year, each over a duration of 10 years. These were judged to be conservative estimates considering on-site surface water is frozen and inaccessible for over three months during the year. The typical exposure time during a wading event was conservatively estimated at 2 hours. Because wading will not expose the entire body to surface water, the skin surface area available for contact was estimated at one-fourth of the available surface area of an older child or adult, or 4500 square centimeters. A drinking water consumption rate of 0.2 liters per occurrence was assumed.

For the dermal contact scenario, the dermal permeability constant of 8.0E-04 cm/hr for water was assumed for VOC indicator compounds without readily available data (USEPA, 1988a). The implication of using a water permeability constant is that compounds are assumed to be carried through the skin as a solute in water rather than being absorbed preferentially or independently (USEPA, 1988a). These and other assumptions are summarized in Table 6-10 along with exposure doses calculated for the exposure pathway.

The equation below was used to estimate exposure doses for dermal contact with on-site surface water (USEPA, 1989a):

$$EXP_{swa} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AVG \times Y}$$

where:

$\text{EXP}_{swa}$ = Average absorbed daily exposure dose (mg/kg/day)
CW = Compound concentration in surface water (mg/l)
PC = Chemical-specific dermal permeability constant (cm/hr)
SA = Skin surface area available for contact ($cm^2$)
ET = Exposure time (hours/day)
EF = Frequency of exposure (days/year)
ED = Duration of exposure (years)
CF = Volumetric conversion factor for water ($10^{-3}$ l/$cm^3$)
BW = Body weight (kg)
AVG = Number of years over which exposure is averaged
(70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year

The equation below was used to estimate exposure doses for incidental ingestion of on-site surface water (USEPA, 1989a):

$$\text{EXP}_{swi} = \frac{CW \times IR \times EF \times ED}{BW \times AVG \times Y}$$

where:

$\text{EXP}_{swi}$ = Average daily exposure dose (mg/kg/day)
CW = Compound concentration in surface water (mg/l)
IR = Ingestion rate (l/day)
EF = Frequency of exposure (days/year)
ED = Duration of exposure (years)
BW = Body weight (kg)
AVG = Number of years over which exposure is averaged
(70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year

Dermal Contact With and Incidental Ingestion of Sediment

As with the scenario for dermal contact with surface water and incidental ingestion, similar events describe the exposure to site sediments. Older children may wade in Brook A or the drainage swale. The typical average body weight assumed for a child age six to fifteen is 30 kilograms. The average, maximum

plausible, and maximum calculated frequencies of exposure of 10, 25, and 25 times per year, respectively, over an exposure duration of 10 years are assumed to be similar to that for surface water.

Sediment contact rates and absorption factors were based upon factors derived for soils. A soil contact rate (500 mg/day) for dermal scenarios, a soil ingestion rate for ingestion scenarios (100 mg/day for older children and adults), and relative absorption factors have been used as derived by EPA. These and other assumptions are summarized in Table 6-11 along with exposure doses calculated for the exposure pathways.

The equation below was used to estimate exposure doses for dermal contact with sediment in Brook A and the drainage swale (USEPA, 1989b):

$$EXP_{sda} = \frac{CSD \times CF \times SCR \times EF \times ED \times RAF}{BW \times AVG \times Y}$$

where:

$EXP_{sda}$ = Average daily absorbed exposure dose (mg/kg/day)
CSD = Compound concentration in sediment (mg/kg)
CF = Conversion factor ($10^{-6}$ kg/mg)
SCR = Soil contact rate (mg/day)
EF = Frequency of exposure (days/year)
ED = Duration of exposure (years)
RAF = Relative dermal absorption factor (unitless)
BW = Body weight (kg)
AVG = Number of years over which exposure is averaged
       (70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year

The equation below was used to estimate exposure doses for incidental ingestion of sediment (USEPA, 1989b):

$$EXP_{sdi} = \frac{CSD \times IR \times CF \times EF \times ED \times RAF}{BW \times AVG \times Y}$$

where:

$EXP_{si}$ = Average daily ingestion exposure dose (mg/kg/day)
CSD = Compound concentration in sediment (mg/kg)
IR = Ingestion rate (mg/day)
CF = Conversion factor ($10^{-6}$ kg/mg)
EF = Frequency of exposure (days/year)
ED = Duration of exposure (years)
RAF = Relative gastric absorption factor (unitless)
BW = Body weight (kg)
AVG = Number of years over which exposure is averaged
(70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year

**Future Use**

Ingestion, Dermal Contact and Inhalation of Vapors From Ground Water Derived From Area 2 Residential Wells

As previously discussed, VOCs have been observed in a discrete portion of the Mottolo site along the southern Mottolo property line, referenced to as Area 2, as well as a limited currently unoccupied area south of the property. Future residential development, and concurrent domestic water supply well installation and use, could feasibly occur in this area. The evaluation included ground water derived from the bedrock aquifer and ground water derived from the overburden aquifer. A rationale for the unlikelihood of ground water use from the overburden aquifer has been presented earlier.

Exposure doses were calculated for the ingestion and dermal contact scenarios according to procedures established in EPA Region I guidance (USEPA, 1989a). However, similar calculations were not performed for the scenario in which compounds could potentially be inhaled during household use of ground water. EPA acknowledges that use of exposure models for this inhalation pathway have not been extensively validated, and indicates that the pathway may be evaluated either qualitatively or quantitatively (USEPA, 1989a). A qualitative evaluation of potential inhalation risks from household ground water use is presented in Section 6.3.2.

Assumptions used to calculate exposure dose for ingestion and dermal contact scenarios included a water consumption rate of 2 liters per day for each day of the year and a lifetime duration of exposure of 70 years. Estimates were calculated for an average adult with an average body weight of 70 kilograms and a body surface area of 19,400 square centimeters. For dermal contact, it was assumed that a person bathes seven times per week for 10 minutes per day (i.e., 0.17 hours) and that all body surface area is immersed during the bathing event. These and other assumptions are summarized in Tables 6-12(A) and 6-12(B) along with exposure doses calculated for the ingestion and dermal contact exposure pathways.

The equation below was used to estimate exposure doses for ingestion of on-site ground water (USEPA, 1989a):

$$EXP_{gwi} = \frac{CGW \times IR \times EF \times ED}{BW \times AVG \times Y}$$

where:

$EXP_{gwi}$ = Average daily exposure dose (mg/kg/day)
$CGW$ = Compound concentration in ground water (mg/l)
$IR$ = Ingestion rate (l/day)
$EF$ = Frequency of exposure (days/year)
$ED$ = Duration of exposure (years)
$BW$ = Body weight (kg)

AVG = Number of years over which exposure is averaged
(70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year


The equation below was used to estimate exposure doses for dermal contact with on-site ground water.

$$EXP_{gwa} = \frac{CGW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AVG \times Y}$$

where:

$EXP_{gwa}$ = Average absorbed daily exposure dose (mg/kg/day)
CGW = Compound concentration in ground water (mg/l)
PC = Chemical-specific dermal permeability constant (cm/hr)
SA = Skin surface area available for contact (cm$^2$)
ET = Exposure time (hours/day)
ED = Duration of exposure (years)
EF = Frequency of exposure (days/year)
CF = Volumetric conversion factor for water ($10^{-3}$ l/cm$^3$)
BW = Body weight (kg)
AVG = Number of years over which exposure is averaged
(70 years for carcinogenic effects; ED for noncarcinogenic effects)
Y = 365 days/year


As previously discussed, significant reduction in ground water compound concentrations are expected to occur during this life-time, future ground water use scenario. Such concentration reductions have been observed to date at the site over the last five years of water quality monitoring. However, no consideration of this declining concentration trend was included in the calculation described above. Thus, the exposure doses presented in Table 6-12 for Area 2 future potential ground water exposure (and Table 6-13 for Area 1) are conservative predictions of potential future exposure which will result in overestimation of associated, predicted potential future risks.

## Ingestion, Dermal Contact, and Inhalation of Vapors From Ground Water Derived From Area 1 Residential Wells

For the purpose of the MBRA, future residential development of Area 1 on the Mottolo site was judged feasible. As such, exposure doses for residential water supply wells in this area have been calculated. The same equations and general parameters used for ingestion and dermal contact of ground water from Area 2 residential wells were also used to estimate exposure doses for ingestion of Area 1 ground water and dermal contact from home use for bathing. The indicator compounds evaluated and the average, maximum plausible, and maximum detected concentrations are different due to the differences in reported compound types and concentrations in ground water samples collected from Area 1 monitoring wells as compared to Area 2 monitoring wells. A qualitative assessment of potential inhalation risks from household use of ground water derived from within Area 1 is presented in Section 6.3.2.

Assumptions used to calculate exposure doses for ingestion and dermal contact of ground water included the use of dermal permeability constants of 9.0E-04 cm/hr and 1.0E-03 cm/hr for toluene and ethylbenzene, respectively. As with the surface water scenarios, the dermal permeability constant for water of 8.0E-04 cm/hr was assumed for VOC indicator compounds without readily available data (USEPA, 1988a). In addition, based on the kinetics of arsenic, no transdermal absorption of this indicator compound was assumed during bathing. Assumptions used for the estimation of exposure doses are summarized in Tables 6-13(A) and 6-13(B) along with exposure doses calculated for the exposure pathways.

## Dermal Contact With and Incidental Ingestion of Soil

The potential route of exposure to subsurface soils for the future scenario should be similar to that of the current scenario with three major exceptions. First, it is assumed that excavation and development of the site may bring contaminated soils

closer to the surface, making compounds in soil more accessible. Second, it is assumed that younger children (ages one to six) would have access to the soil while playing in their yard and that adults would be involved in gardening. Average body weights of 10 kilograms and 70 kilograms, were used to account for these younger children and adults, respectively. Third, with the population closer to the exposure point, the frequency of occurrence would be expected to be greater. Thus, a frequency of exposure of 78 times per year for the average scenario and a frequency of exposure of 160 times per year for the maximum plausible and maximum calculated scenarios was assumed. The lifetime duration period of 70 years was used despite the fact that VOCs in surface and near surface soils will tend to gradually volatilize to ambient air or be carried downward through surface water percolation as evidenced by current site conditions. The EPA-derived soil ingestion rate of 200 mg/day for children from one to six years of age and the soil ingestion rate of 100 mg/day for ages six to adult were used (USEPA, 1989b). A soil contact rate of 500 mg/day is suggested for use by EPA for purposes of consistency (USEPA, 1989b).

The same equations used in current soil dermal contact and ingestion scenarios were used to estimate future exposure doses for dermal contact with soil and to estimate future exposure doses resulting from incidental ingestion. Unlike the current soil ingestion scenario, the future scenario for incidental ingestion was assessed by evaluating potential risks of ingestion for two separate age groups, ages one to six and ages seven to 70. This tended to weight the calculated exposures doses toward risks to younger children, as the soil ingestion rates used for children ages one to six were twice those of other age groups. Ratios of the calculated exposure doses were combined to provide an exposure dose estimate over a lifetime duration of 70 years. A similar breakdown of age groups was not employed for the dermal contact scenario. Assumptions used for these calculations are summarized in Table 6-14 along with the exposure doses calculated for the exposure pathways.

## Dermal Contact With and Incidental Ingestion of Surface Water

The route and nature of exposure to surface water is expected to be similar to current conditions existing at the Mottolo site; however, the frequency and duration of the exposure would likely be greater upon future development. This would result primarily from increased accessibility to Brook A and the drainage swale. Thus, average, maximum plausible and maximum calculated exposure rates of twice that for the current scenarios, or 20, 50 and 50 times per year, respectively, were assumed. The duration of exposure was increased from 10 years under the current scenario to 15 years to account for increased accessibility of the exposure points to younger children. A body weight of 20 kilograms was used as the average weight of a child ages one to fifteen.

The same equations used for the current scenarios, dermal contact with and incidental ingestion of surface water, were used to estimate future exposure doses. Assumptions used for these calculations are summarized in Table 6-15 along with the exposure doses calculated for these exposure pathways.

## Dermal Contact With and Incidental Ingestion of Sediment

Similar to future surface water scenarios, an increase in the frequency of wading or other activities in Brook A or the drainage swale is likely to occur should residential development of the area proceed at a future time. Average and maximum plausible, and maximum calculated frequencies of exposure of 20, 50 and 50 times per year, respectively, over a duration of 15 years were assumed for a child with an average weight of 20 kilograms. The EPA-derived soil contact rate of 500 mg/day was used to estimate dermal exposure, and an ingestion rate of 150 mg/day was used for the incidental ingestion scenario, an average of the 200 mg/day rate for a child ages one to six and the 100 mg/day rate for an adult (USEPA, 1989b).

The same equations used for the current scenario, dermal contact with and incidental ingestion of soil, were used to estimate exposure doses. Assumptions used for these calculations are summarized in Table 6-16 along with the exposure doses calculated for these exposure pathways.

## 6.3 RISK CHARACTERIZATION

The Risk Characterization evaluates potential current and future health threats associated with Mottolo site conditions based on selected indicator compounds. Within the Risk Characterization, site-specific risks are characterized by integrating data developed in the Hazard Identification and Dose-Response Assessment and Exposure Assessment.

### 6.3.1 Risk Evaluation Methodology

The risk evaluation is the final stage of a baseline risk assessment. It involves the comparison of exposure doses and reference doses for noncarcinogens and the comparison of calculated risks and target risks for carcinogens. Methodologies for evaluating noncarcinogenic and carcinogenic risks for the selected indicator compounds are presented below (USEPA, 1989a).

**Noncarcinogenic Risk Evaluation**

For many sites, it is necessary to assess several indicator compounds with regard to their potential noncarcinogenic effects on human health. Noncarcinogenic risks are evaluated in terms of a threshold-response theory which assumes that multiple subthreshold exposures could possibly result in adverse health effects (USEPA, 1986).

The hazard index is used as a means of assessing potential risk from noncarcinogenic health effects; however, it is not a mathematical prediction of

incidence or severity of effects (USEPA, 1986). The hazard index is calculated for each noncarcinogen indicator compound by dividing the exposure dose in mg/kg/day by the reference dose (RfD), also in mg/kg/day, to calculate a unitless estimate of risk. If the hazard index is less than one, risks associated with exposure to the compounds under evaluation are not considered to be significant, largely because of the built-in conservatism involved in deriving the RfD. When the hazard index exceeds one, further evaluation of the toxicity of the indicator compound and the associated assumptions is needed. This can often resolve whether the compound should be of concern as a potential health risk or whether the hazard index simply reflects an extremely high uncertainty associated with the derivation of the specific RfD.

Hazard indices are typically summed for each indicator compound within each exposure pathway to provide a measure of the total risk for the chemical mixture without regard to the specific toxic effect of each indicator compound. When this summed hazard index exceeds one, endpoints of concern (i.e., target organs) for toxic effects are considered. In these situations, hazard indices are calculated for each different endpoint of concern within the exposure pathway.

**Carcinogenic Risk Evaluation**

Evaluation of the incremental lifetime cancer risk depends in part on the nature of the experimental data used by EPA to designate the individual indicator compounds as carcinogens. When based on animal data, the incremental lifetime cancer risk corresponds to the upper 95th percentile of the probability of developing cancer, while if based on human data, it is a maximum likelihood estimate (USEPA, 1989b). In both cases, potential carcinogenic effects are assumed over a lifetime of 70 years.

The incremental lifetime cancer risk is calculated by multiplying the exposure dose in mg/kg/day by the cancer potency factor (CPF) in $(mg/kg/day)^{-1}$ to obtain a

unitless estimate of risk. Implicit in these calculations is that the exposure dose is considered an average daily exposure dose over the lifetime. As a consequence, the predicted risk may overestimate actual site risk (USEPA, 1986). The resulting estimate is therefore an upper-bound estimate of the potential carcinogenic risk at an exposure point.

## 6.3.2 Risk to Human Health

The potential risks to human health were evaluated for each exposure pathway identified in the Exposure Assessment under current and future land-use conditions. The intent was to provide reasonable and extremely conservative assessments of the degree of risk associated with exposure to indicator compounds via the exposure pathway, and to identify pathways of concern which may warrant attention in the FS.
Generally, noncarcinogens and carcinogens are considered for each exposure pathway. However, several of the indicator compounds selected for each environmental medium at the Mottolo site have not been designated by EPA as carcinogens and were therefore evaluated only in terms of noncarcinogenic risk. In addition to the calculated risk estimates, the information used to arrive at these figures from earlier stages of the MBRA are summarized in tables for each exposure pathway.

**Current Land-Use Conditions**

<u>Dermal Contact With and Incidental Ingestion of Soil</u>

The current risk of exposure by older children to the noncarcinogens ethylbenzene, toluene, and total xylenes in site soils was examined as a potential exposure pathway. Hazard indices calculated for dermal exposure or incidental ingestion of site soils were calculated to be far below the value of one, indicating that potential exposure risks via these pathways are extremely low. Calculated hazard indices

and a summary of pertinent data for dermal contact and for incidental ingestion of site soil are shown in Table 6-17.

The highest summed hazard index for the maximum calculated scenarios for dermal contact and incidental ingestion, were estimated to be 4E-04 and 1E-04, respectively, reflecting the relatively low exposure doses and low toxicities for the indicator compounds. Given the conservative assumptions applied in earlier stages of the MBRA, the actual site risks via these exposure pathways are likely to be even lower.

Dermal Contact With and Incidental Ingestion of Surface Water

The current risk of exposure by children ages one to fifteen to the potential carcinogen 1,1-dichloroethane and the noncarcinogen 1,2-dichloroethene (total) in site surface water was examined as a potential exposure pathway. Incremental lifetime cancer risks for dermal exposure or incidental ingestion of 1,1-dichloroethane in site surface water were well within the target range of risks. Moreover, hazard indices were far below the value of one, indicating that potential exposure risks via these pathways are unlikely to be of concern. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for dermal contact and for incidental ingestion of site surface water are shown in Table 6-18.

Unlike the situation for exposure to site soil, the highest risk estimates for a maximum calculated scenario was via the incidental ingestion pathway rather than via dermal contact. However, the maximum calculated incremental lifetime cancer risk of 2E-07 and the maximum calculated hazard index value of 2E-04 again reflect the low exposure doses, low carcinogenic potencies and low toxicities for the indicator compounds.

## Dermal Contact With and Incidental Ingestion of Sediment

The current risk of exposure by older children ages six to fifteen to the carcinogen 1,1-dichloroethane and the noncarcinogen 1,1,1-trichloroethane in site sediment was examined as a potential exposure pathway. Similar to the surface water exposure pathways, the calculated carcinogenic risks were far within the target range of 1E-04 to 1E-06. Hazard indices for dermal exposure or incidental ingestion of site sediment were calculated to be far below the value of one. Therefore, potential exposure risks via these pathways are unlikely to be of concern. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for dermal contact and for incidental ingestion of site sediment are shown in Table 6-19.

The highest lifetime cancer risks for the maximum plausible and maximum calculated scenarios for 1,1-dichloroethane were 3E-10 for incidental ingestion and 1E-09 for dermal contact. The summed hazard indices for the maximum plausible and maximum calculated scenarios for 1,1,1-trichloroethane were 4E-07 for incidental ingestion compared to 2E-07 for dermal contact. These values also reflected low exposure doses, low carcinogenic potency and low toxicity, as appropriate, for 1,1-dichloroethane and 1,1,1-trichloroethane.

## Summary of Current Land-Use Risks

As previously discussed, risks associated with individual exposure pathways for current land uses at the Mottolo site are far below target levels. The sums of each of these estimated risks, for average, maximum plausible, and maximum calculated exposure scenarios, are also several orders of magnitude below target risk levels established by EPA. On this basis, current site conditions are not expected to pose significant potential hazards to the public.

**Future Land-Use Conditions**

Ingestion of and Dermal Contact to Ground Water From Area 2 Residential Wells
Installed in Bedrock

The future risk of exposure by adults to indicator compounds in ground water
upon installation of private bedrock wells within Area 2 was evaluated.
Noncarcinogenic indicator compounds included 1,2-dichloroethene (total) and
tetrahydrofuran, while trichloroethene was evaluated as a carcinogenic compound.
Calculated incremental lifetime cancer risks, hazard indices, and a summary of
pertinent data for ingestion and dermal contact of ground water derived from
bedrock within Area 2 are shown in Table 6-20 (A).

Risks associated with potential ingestion of ground water derived from bedrock
appeared to be driven by the presence of trichloroethene, which was calculated to
have an incremental lifetime cancer risk of 3E-04 for the maximum calculated
exposure pathway, 2E-04 for the maximum plausible exposure pathway, and 9E-05
for the average exposure pathway. It should be noted that the average estimated
risk is within the target risk criterion of 1E-04 to 1E-06, typically used by EPA to
assess carcinogenic risk; the maximum plausible and maximum calculated
exposure risks only slightly exceeded this range. The uncertainty associated with
the derivation of the provisional oral RfD for tetrahydrofuran is evidenced by the
fact that the hazard index is driven just above one due to the use of the value.
However, it is unlikely that this borderline value represents a true risk for
ingestion.

Lifetime cancer risks for dermal contact were approximately three orders of
magnitude less than for ingestion pathways, and were therefore not considered a
major concern. Likewise, hazard indices for dermal contact were well below one,
indicating that potential exposure risks via this pathway are extremely unlikely.

## Ingestion of and Dermal Contact of Ground Water From Area 2 Residential Wells Installed in Overburden

Although the installation of productive overburden wells at the Mottolo site is not considered feasible, risk estimates were calculated for hypothetical domestic wells drawing from the overburden within Area 2. Trichloroethene, 1,2-dichloroethene (total) and tetrahydrofuran were evaluated as indicator compounds. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for ingestion and dermal contact of ground water derived from overburden within Area 2 are shown in Table 6-20(B).

Unlike risk estimates calculated for ground water from Area 2 bedrock, the incremental lifetime cancer risks for ingestion or dermal contact scenarios were within the target risk criterion of 1E-04 to 1E-06 for average, maximum plausible, and maximum calculated exposure conditions. Similarly, hazard indices calculated to evaluate noncarcinogenic risks for ingestion and dermal contact scenarios were below one, and therefore below target levels. Hazard index values for the ingestion scenario ranged from 7E-02 to 1E-01 and values for dermal contact ranged from 1E-04 to 2E-04.

## Ingestion of and Dermal Contact to Ground Water From Area 1 Residential Wells Installed in Bedrock

The future risk of exposure by adults to indicator compounds in ground water upon installation of private bedrock wells within Area 1 was also evaluated. This exposure pathway considered the greatest variety of indicator compounds. Toluene, 1,1,1-trichoroethane, 1,2-dichloroethene (total), ethylbenzene, and tetrahydrofuran were evaluated as noncarcinogenic indicator compounds, while arsenic, 1,1-dichloroethane trichloroethene, and vinyl chloride were evaluated as potential carcinogens. Calculated incremental lifetime cancer risks, hazard

indices, and a summary of pertinent data for ingestion and dermal contact of ground water from bedrock within Area 1 are shown in Table 6-21 (A).

Risks associated with potential ingestion of ground water derived from bedrock appear to be driven nearly equally by the presence of vinyl chloride and arsenic, with the summed incremental lifetime cancer risks for the average and maximum plausible exposure pathways calculated at 3E-03 and 6E-03, respectively. Incremental lifetime cancer risks for the extremely conservative maximum calculated scenario were 3E-02. These levels are greater than the target risk criterion of 1E-04 to 1E-06, typically used by EPA to assess carcinogenic risk. Unlike the ground water derived from bedrock within Area 2, the presence of trichloroethene was not a major factor in describing potential cancer risks for ground water derived from bedrock within Area 1. The summed hazard indices for ingestion of ground water were calculated as slightly above one for noncarcinogenic compounds, with the value attributed almost exclusively to the presence of tetrahydrofuran. As discussed in the Area 2 bedrock ground water scenario, these values appear inflated due to uncertainty in the derivation of the oral RfD for tetrahydrofuran, and are unlikely to present potential risks comparable to the incremental lifetime cancer risks.

Lifetime cancer risks for dermal contact were significantly less than for ingestion pathways, at 3E-06, 5E-06, and 3E-05 for the average, maximum plausible, and maximum calculated exposure pathways, respectively. Hazard indices for dermal contact with noncarcinogens were well below one, indicating that potential exposure risks via this pathway are extremely unlikely.

Since water consumption and bathing are activities commonly performed by individuals over a lifetime, the incremental lifetime cancer risks were summed over the dermal and ingestion exposure pathways to assess multiple exposure pathway risks. As a result of the low incremental lifetime cancer risk for dermal

contact, the value calculated by summing these risks across the ingestion and dermal exposure pathways was similar to that of the ingestion pathway alone.

## Ingestion of and Dermal Contact to Ground Water from Area 1 Residential Wells Installed in Overburden

As previously discussed, the installation of productive overburden wells at the Mottolo site is not considered feasible. Nevertheless, risk estimates were calculated for hypothetical domestic wells drawing from overburden within Area 1. The indicator compounds evaluated were the same as those used in the evaluation of ground water derived from bedrock within Area 1: arsenic, 1,1-dichloroethane, 1,2-dichloroethene (total), ethylbenzene, tetrahydrofuran, toluene, 1,1,1-trichloroethane, trichloroethene, and vinyl chloride. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for ingestion and dermal contact of ground water derived from overburden within Area 1 are shown in Table 6-21(B).

Summed risk estimates for ground water derived from overburden within Area 1 were nearly identical to those calculated for bedrock within Area 1. For the ingestion scenarios, incremental lifetime cancer risks were outside the EPA target risk criterion and noncarcinogenic hazard indices exceeded one. The individual contribution of compounds to the summed hazard index was more evenly distributed than it was for the Area 1 bedrock scenarios, in which noncarcinogenic risks were driven by the presence of tetrahydrofuran. As with the Area 1 bedrock scenarios, calculated risk estimates for dermal contact with ground water involving Area 1 overburden were within target levels for carcinogens and noncarcinogens.

## Inhalation of Vapors From Ground Water Derived From Within Area 1 and Area 2

A qualitative evaluation of vapors potentially emanating from ground water during household use was performed. Activities possibly resulting in a release of vapors

into indoor air include use of showers, baths, toilets, dishwashers, and washing machines. It is assumed that each of these activities would occur in private residences following possible future development of the Mottolo site.

Exposure models suggest that the most important factors influencing actual exposure dose in household situations are the fraction of the compound available for inhalation uptake, the breathing rate of the individual, and the transfer efficiency of the compound from water to surrounding air (McKone, 1987). Estimates of the first two factors can vary widely, but are often used to address inhalation exposure. The amount of compound available for inhalation uptake at the Mottolo site can be represented as the estimated exposure point concentrations for ground water presented earlier in Table 6-8. Breathing rates vary depending on the activity involved, and the age and physical characteristics of the individual. Thus, a particular quality of the compound, i.e., the transfer efficiency of the compound from water to air, is a critical consideration in evaluating inhalation exposure doses.

A poor transfer efficiency indicates that the compound concentrations in ground water may not necessarily result in a linear inhalation exposure dose. Among the nine indicator compounds identified at the Mottolo site for Area 1 and Area 2 ground water, arsenic and tetrahydrofuran appear to meet the criteria of compounds with poor transfer efficiencies. Arsenic, an inorganic element, is unlikely to volatilize under most circumstances in the household, while tetrahydrofuran with a vapor pressure of 0.173 atmospheres at 20°C is much less likely to volatilize than the other indicator VOCs which exhibit considerably greater vapor pressures.

Experimental dose estimates reported for VOCs in household air indicate that the ratio of inhalation dose to ingestion dose for a unit concentration of 1 mg/L may range from 1 to 6 (McKone, 1987). However, the uncertainty involved in the estimation of these potential inhalation exposure doses was noted, as much of

these data were based on simulations which may or may not be typical of conditions encountered in private residences. Moreover, it was cautioned that the importance of the inhalation exposure pathway may not be fully quantified without better characterization of the variabilities in parameters used to derive these ratios.

Given the uncertainty involved in the estimation of inhalation exposure dose associated with household ground water use, it nevertheless appears that this may be an important exposure pathway. While it is difficult to apply simulation-based ratios to ground water conditions encountered at the Mottolo site, it is recognized that ground water containing the highest concentrations of VOCs may be associated with the greatest potential risks. Indicator compounds, with the exception of arsenic and tetrahydrofuran, for ground water derived from bedrock or overburden within Area 1 may present the greatest risks for inhalation exposure during household use. Risks associated with use of ground water derived from overburden or bedrock within Area 2 would be expected to be considerably less. Note that the calculated risk estimates for Area 1 have previously been described as outside target levels for the ingestion scenarios, but that calculated risk estimates for Area 2 were below or near target levels.

Dermal Contact With and Incidental Ingestion of Soil

The future risk of lifetime exposure to the noncarcinogens ethylbenzene, toluene, and total xylenes in site soils was examined as a potential exposure pathway. Hazard indices calculated for dermal exposure or incidental ingestion of site soils were somewhat higher than those for the current exposure pathway but were still far below the value of one, indicating that potential exposure risks via these pathways are also likely to be negligible. Calculated hazard indices and a summary of pertinent data for dermal contact and for incidental ingestion of site soil are shown in Table 6-22.

## Dermal Contact With and Incidental Ingestion of Surface Water

The future risk of exposure by children ages one to fifteen to the potential carcinogen 1,1-dichloroethane and the noncarcinogen 1,2-dichloroethene (total) in site surface water was examined as a potential exposure pathway. Incremental lifetime cancer risks calculated for dermal exposure or incidental ingestion of site surface water were slightly greater than for the current scenarios; however they were several orders of magnitude below the target risk range criterion of 1E-04 to 1E-06, typically used by EPA. Hazard indices presented a similar pattern with values far below one, indicating that potential exposure risks via these pathways are likely to be negligible. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for dermal contact and for incidental ingestion of site surface water are shown in Table 6-23.

## Dermal Contact With and Incidental Ingestion of Sediment

The current risk of exposure by children ages one to fifteen to the potential carcinogen 1,1-dichloroethane and the noncarcinogen 1,1,1-trichloroethane in site sediment was examined as a potential exposure pathway. As with the surface water scenarios, calculated risk estimates for dermal exposure or incidental ingestion of site sediment were somewhat greater in the future scenario than under the current scenario; however, hazard indices were still far below the value of one, and incremental lifetime cancer risks were several orders of magnitude below the target risk range of 1E-04 to 1E-06. Calculated incremental lifetime cancer risks, hazard indices, and a summary of pertinent data for dermal contact and for incidental ingestion of site sediment are shown in Table 6-24.

## Summary of Future Land-Use Risks

With the exception of domestic use of ground water extracted from bedrock within Area 1, risks associated with individual average exposure pathways for potential

future land uses at the Mottolo site were near or below target levels. Summation of estimated risk associated with average exposure scenarios resulted in an aggregate hazard index of just above one, for noncarinogens, and an aggregate incremental lifetime carcinogenic risk of 3E-03, greater than the target risk range of 1E-04 to 1E-06. The vast majority of these aggregate risks are associated with potential future use of ground water from Area 1 for domestic purposes.

Estimated risks for use of ground round derived from overburden within Area 1 presented a similar pattern as risks estimated for use of ground water derived from bedrock within Area 1; however, these values do not reflect actual site risks via this pathway. Installation and domestic use of overburden wells within either Area 1 or Area 2 is not considered feasible, and site risks due to ingestion of ground water derived from overburden are unlikely.

## 6.3.3 Risk to the Environment

Potential risks to the environment were evaluated in a qualitative fashion due to the relative importance of human receptors compared to environmental receptors at the site. During this evaluation, significant environmental receptors were not identified which would warrant further consideration using a quantitative evaluation process. The evaluation involved describing baseline environmental conditions and then assessing potential current and future risks to various aspects of the site environment.

### Baseline Environmental Conditions

A discussion and identification of flora and fauna known or expected to be present at the Mottolo property has been compiled to describe the baseline biological setting. The presence of critical habitats of endangered species and other sensitive environments within the study area was also considered. Flora and fauna at the Mottolo property were assessed with information obtained from the

RI wetlands investigation, the New Hampshire Natural Heritage Inventory (NHNHI), the New Hampshire Department of Fish and Game (NHDFG), and the literature.

Based upon this review, it was concluded that a wide range of habitats are likely to be available for flora and fauna at the Mottolo property, given the existence of forested and cleared areas, the presence of Brook A and associated wetlands, and the varying topographic relief. Sensitive environments warranting detailed evaluation as defined in USEPA (1989d) were not identified within the study area.

Flora

Forests of the type occupying the Mottolo property have been described as transitional between the pure coniferous forests of the more northern latitudes and the mixed deciduous forests of the more southern latitudes (Sutton and Sutton, 1986). Moreover, the forested areas of the Mottolo property are typical of New England forests which exhibit a relatively new growth of trees following successive clearings, although it is apparent that the property has not been completely cleared for many years.

Common trees associated with the forested areas of the site include red maple, gray birch, white pine, eastern hemlock, and northern red oak. Flora associated with wetland areas of the site include red maple, swamp azalea, winterberry, sensitive fern, and sphagnum moss. Some of the prevalent flora found to be present in cleared areas with disturbed soils include various grasses, staghorn sumac, goldenrods, asters, and clover. A more detailed description of on-property flora is provided in the wetlands investigation presented in Section 2.7. A list of flora identified at the Mottolo property is shown in Table 2-25.

## Fauna

A diverse fauna is expected to be associated with the Mottolo property due to the wide range of available habitats. Species assemblages are likely to be typical of those encountered in transitional forests throughout much of southern New England (Sutton and Sutton, 1986). Many of the species may be more confined to forested areas of the property such as white-tailed deer, eastern chipmunk, and gray squirrel, which were observed during RI field activities. Species such as the deer mouse and white-footed mouse are more likely to be present in cleared areas. Abundant bird populations are probably present in the forested areas and at the borders where the forested areas meet the cleared areas. Bird species observed at the site include chickadees, nuthatches, woodpeckers, and other birds common to the region. Amphibian and reptile species may be most prevalent in and along the broad wetlands to the south of the Mottolo property, and less common in Brook A where the water flow is greater. Likely inhabitants of Brook A are amphibians and insect larvae. A list of common mammals, birds, reptiles, and amphibians likely to be found at the Mottolo property is provided in Table 6-25.

## Sensitive Environments

According to EPA, sensitive environments are those environments which merit special consideration in the risk assessment because of their ecological significance or because of their value in terms of aesthetics, recreation or economics (USEPA, 1989c). Sensitive environments may include habitats which are unique or unusual, habitats necessary for the continued propagation of rare or endangered species, or habitats of regionally important sport species. Either wetland or terrestrial habitats may meet these criteria. Wetlands and some upland areas associated with the Mottolo site have been previously described in Section 2.7. The extent of wetlands along the Brook A valley is shown in Figure 2-14 and is

estimated to include approximately 3 acres of which approximately 50 percent is within the Mottolo property.

Review of available information suggests that the wetland and terrestrial habitats and associated species found in the site area do not constitute sensitive environments. The local environment appears typical of northeast transitional forests and therefore does not appear to be unique or unusual. Furthermore, the NHNHI (1990) has indicated that there are no known federal or state rare plants, animals, or exemplary natural communities within the site area. Lists of federal and state endangered and threatened species (NHNHI, 1989) have also been reviewed which support the findings that no known critical habitats of federal or state endangered species occur within the site area. The site area has not been designated by the U.S. Department of the Interior (DOI) as a natural resource concern.

The site area is not currently designated by the New Hampshire Department of Fish and Game for recreation, or for sport hunting or fishing; however, it has been used for hunting in the past. Wildlife breeding areas or wildlife refuges are not present within the study area (NHDFG, 1990). Important floodways or floodplains have not been identified at the Mottolo site (FEMA, 1982).

Ambient Water Quality Criteria for Indicator Compounds

Ambient Water Quality Criteria (AWQC) for freshwater organisms were reviewed for applicability to the MBRA. AWQCs are generally derived from a minimum data base of acute and chronic responses for a variety of organisms. However, as indicated by the values presented in Table 6-26, AWQC concentrations have not been developed for most indicator compounds at the Mottolo site. Several of the values were therefore obtained from IRIS, and although they do not constitute criteria, they represent the lowest effect level (LEL) from the literature.

The maximum VOC concentration reported in surface water samples collected from Brook A or within the drainage swale was for 1,1-dichloroethane at 0.041 mg/l; AWQCs have not been established for this compound. The next highest reported VOC concentration was 0.015 mg/l for 1,1,1-trichloroethane. AWQCs have not been established for this compound either. Similar patterns occur when comparing other maximum detected concentrations to acute LEL values; 1,2-dichloroethene (total) with a maximum concentration of 0.009 mg/l compared to 11.6 mg/l, toluene with a maximum concentration of 0.01 mg/l compared to 17.5 mg/l, and trichloroethene with a maximum concentration of 0.004 mg/l compared to 45 mg/l.

That the AWQC and LEL values are so much greater than the concentrations reported in surface water at the Mottolo site suggests that compounds reported at these low levels are unlikely to present a measurable acute response in freshwater organisms. Ecological parameters such as morbidity, fecundity, and rate of development are often used to measure environmental stress. It is equally unlikely that chronic values, if available, would be so low to suggest that certain organisms in the community might be sensitive to long-term exposure to low concentrations.

**Current Environmental Risks**

At present, no known risks to the environment have been identified. Visible signs of environmental stress associated with past waste disposal activities have not been recorded during RI field activities. More importantly, compound concentrations in Brook A surface water and sediment were reported at or near background concentrations at most of the sampling locations, and surficial soils in the small area near the former drum disposal area have relatively low contaminant concentrations. It therefore appears that few likely exposure points exist for site biota. The low compound concentrations reported for samples collected from a few of the surface water and sediment sampling stations are likely to have little or no effect on species associated with these environmental media. It

is also likely that viable populations of flora and fauna are currently similar to those encountered in forested and wetland areas adjacent to the Mottolo property.

**Future Environmental Risks**

As with current environmental risks at the Mottolo site, future risks are also likely to be negligible. Contaminant concentrations, currently at low levels, are likely to decrease over time. The most significant future impacts would likely result from potential residential development of the site. It is presumed that wetlands on the Mottolo property will not be developed, and will maintain a prominent role in the ecosystem. However, under conditions of development, habitats available to wildlife are likely to be greatly reduced, with a corresponding reduction in the diversity of species. Assuming development proceeds at some future time, species assemblages should become similar to those now occupying residential areas adjacent to the Mottolo property.

### 6.3.4    Uncertainties and Limitations of the Risk Assessment

Uncertainties are inherent to each stage of the risk assessment process. It is therefore important to identify those uncertainties most critical to the evaluation and to consider their possible impact on the estimation of site risk. This process serves as a check to assess whether selected indicator compounds, site exposure pathways, exposure parameters, and estimated exposure doses are reasonable indicators of potential exposure to compounds and associated risk attributed to the site.

**Site-Specific**

The risk assessment is dependent on the quality and nature of the sampling data from the site characterization. Some factors contributing to the uncertainty in

sample data have been considered previously. These include possible skewing of data as a result of biased selection of sampling locations or analytical parameters.

In particular, because a principal objective of the RI was to describe the nature and extent of contamination present within the Mottolo study area, the resultant data base is more reflective of contaminated areas as compared to the total site area. The frequency of compound detection as well as calculated exposure point concentrations are thus both biased to the high side which tends to result in overestimation of potential site risks.

Efforts have been undertaken to limit one aspect of sampling bias by collecting ground water and surface water samples at different times of the year. This tends to account for seasonal changes in compound concentrations; however, these sample data do not reflect long-term trends or fluctuations.

**Hazard and Dose Response Assessment**

The initial selection of indicator compounds carries a degree of uncertainty, especially when the list of detected compounds at the site is extensive. Potential health effects may be underestimated for compounds not included in the final list of indicator compounds because little toxicity information has been established or because of other data limitations. Moreover, the toxicity constants developed by EPA and used to select indicator compounds, are typically considered a preliminary screening tool. Uncertainty has been limited somewhat in the MBRA with a hierarchical approach to selection of indicator compounds, which in addition to toxicity constants, also considers factors such as frequency of occurrence, concentration, and relation of compound concentrations to background levels and applicable drinking water standards.

Uncertainty also exists in the derivation of the individual RfDs and CPFs for the selected indicator compounds. A series of uncertainty factors are typically applied

by EPA when deriving the RfD which may result in substantial overestimation of compound toxicity because adequate or sufficient experimental data are not available. A factor of 10 may be applied to the derivation of the RfD in each of the following circumstances: when accounting for population variations, when extrapolating from animals to humans, when using a subchronic study, or when using a Lowest Observable Adverse Effect Level (LOEL) as the basis of calculation. An additional modifying factor can also be applied. This type of overestimation was particularly evident in the EPA-derived provisional oral RfD for tetrahydrofuran with a combined uncertainty factor of 10,000, largely due to the fact that the compound has not been well studied (Hurst, 1990).

## Exposure Assessment

The methodologies involved in calculating average and maximum plausible exposure point concentrations may result in overestimation or underestimation. Careful selection of exposure assumptions is necessary to provide the most reasonable estimates of average and maximum plausible exposure doses. One conservative assumption included in the MBRA is that exposure doses for carcinogens have been derived assuming that the values are the average daily doses over a 70-year lifetime even though potential exposures to carcinogens at the Mottolo site would probably be over less than a lifetime. This particular assumption will result in a more conservative (upper end) estimation of potential site risks. Use of a maximum detected concentration as an exposure point concentration provides another degree of conservatism to the calculations, as it is unlikely that exposures of this magnitude would reasonably occur over a future period of time.

## Risk Evaluation

Uncertainty in the risk evaluation is largely the by-product of uncertainties presented in earlier stages of the MBRA. Because uncertainties exist in

dose-response estimates, EPA has chosen to quantify risk using the upper 95 percent confidence interval, which results in overestimation of actual site risks.

Risk summation techniques apply additional uncertainty by assuming that intakes of the indicator compounds are small. They assume independence of action by the compounds involved and provide no means of incorporating potential synergistic effects or antagonistic chemical interactions into the calculations. Overestimation or underestimation of multiple substance risks can therefore result if these assumptions are incorrect. In turn, the total cancer risk estimate may be artificially more conservative, as risks from a number of different carcinogens are assumed.

## 6.4 SUMMARY AND CONCLUSIONS

In summary, the MBRA resulted in the selection of nine indicator compounds for ground water, two indicator compounds for surface water, two indicator compounds for sediment, and three indicator compounds for soil. The list of site indicator compounds includes arsenic, 1,1-dichloroethane, 1,2-dichloroethene (total), tetrahydrofuran, 1,1,1-trichloroethane, trichloroethene, toluene, vinyl chloride, and total xylenes. Among the selected indicator compounds, arsenic, 1,1-dichloroethane, trichloroethene, and vinyl chloride have been designated as carcinogens by EPA.

The generally low values for the calculated risk estimates suggest that risks to human health are negligible for the majority of pathways evaluated for the Mottolo site. Those pathways with low values for calculated risks include dermal contact and incidental ingestion of site surface water, site sediment, and site soil for both current and future exposure pathways associated with each of these environmental media. As described previously, the risk values derived for these pathways are based on conservative assumptions of exposure frequency, exposure

duration, and exposure dose, and are applied over a lifetime or specifically to children.

Current risk from ingestion of ground water was not evaluated as there are presently no exposure pathways. However, future risk estimates for potential ingestion of ground water derived from bedrock within portions of the Mottolo site referred to as Area 1 were found to be outside of the target range of risk; risk estimates were found to border on target levels for ground water derived from bedrock within Area 2. Current or future exposure risks via dermal contact with ground water derived from bedrock within either Area 1 or Area 2 are likely to be very low.

Risks associated with the ingestion and dermal contact with ground water derived from the overburden within Area 1 and Area 2 were evaluated independently from bedrock ground water use. The calculated risk values suggest that only the ingestion scenario for ground water derived from the overburden within Area 1 would carry unacceptable risks. However, as previously discussed, a domestic water supply well could not be feasibly installed in Area 1 overburden.

While carcinogenic risk estimates for ingestion of arsenic in ground water were calculated to be outside the target range of 1E-04 to 1E-06, the manner of evaluating the carcinogenicity of arsenic represents an area of debate (USEPA, 1988b). Arsenic has been reported as a Class A carcinogen by EPA, based on experimental evidence. However, data from animal studies suggests arsenic may also have a role as an essential nutrient. Therefore, unlike many carcinogens where a no threshold value is established, it appears there may be some intake level at which the deleterious effects of arsenic nutrient deprivation outweigh those from arsenic carcinogenicity. Furthermore, the form of the arsenic (organic, inorganic, trivalent or pentavalent) also plays a significant role in the toxicity of

arsenic with some forms of arsenic being much less toxic than others. It therefore appears that use of arsenic carcinogenicity as the sole means of evaluating risk of exposure to this constituent in ground water may be misleading, and may significantly overestimate associated incremental cancer risks.

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Section 7

# 7.0 SUMMARY AND CONCLUSIONS

Background information on the Mottolo site is summarized in this section as well
as conclusions regarding hydrogeologic conditions, the distribution of
contaminants, contaminant fate and transport, and risks posed by contaminants
present at the site.

## 7.1    BACKGROUND

The Mottolo site is bounded to the north by a rural residential neighborhood, to
the south and east by properties planned for residential development, and to the
west by several residences and undeveloped land.  The site comprises
approximately 50 acres of primarily undeveloped, heavily wooded land and is
traversed by Brook A, a perennial stream which originates beyond the southern
property boundary, flows north through the property, and eventually discharges to
the Exeter river.  Approximately two acres of land remains cleared from the
former piggery operated on site and the 1980/1980 U. S. Environmental Protection
Agency (EPA) removal action; a piggery building and several concrete foundation
pads are present in the southern part of the cleared area.  The cleared area is
divided by a drainage swale in which an intermittent stream flows from the
western portion of the property east to Brook A.  Land elevation in the Mottolo
site area ranges from approximately 230 feet above mean sea level (MSL) in the
upland piggery building area to approximately 165 feet MSL to the east along the
Brook A valley.

From 1975 through 1979, approximately 1600 55-gallon drums and 5-gallon pails
containing liquid and solid waste materials were disposed of on the hillside north
of the piggery building located on site.  Investigations conducted by the
New Hampshire Water Supply and Pollution Control Commission (WSPCC) in
1979 indicated that the disposal area was contaminating soils, surface water, and
ground water with volatile organic compounds (VOCs) such as 1,2-dichloroethene,

1,1,1-trichloroethane, trichloroethene, toluene, ethylbenzene, xylenes and tetrahydrofuran.

During 1980, the EPA excavated the drums and pails and staged them on site pending approval of transportation off site for disposal. During the ensuing years, ground water investigations conducted by the WSPCC indicated the presence of a relatively limited area of overburden and bedrock ground water contamination extending from the former disposal area east to Brook A. During this same period, the WSPCC monitored ground water quality in residential wells located north of the Mottolo site; only trace concentrations of VOCs were reported present in the samples collected during this program.

During the Remedial Investigation (RI), a second source area of VOCs was identified on the Mottolo site. This area is located beneath or in close proximity to a concrete pad located west of the piggery building which was used by EPA as a drum staging area during their 1980/1981 response action.

## 7.2    STUDY AREA CHARACTERISTICS

The majority of the upland study area is covered with a thin layer of glacial till generally ranging from 0 to 15 feet in thickness. The glacial till identified on site is an ablation till primarily consisting of fine to coarse sand with boulders and gravel. The relatively small percentage of gravel, silt and clay in these deposits and the presence of stratification identified in some samples indicates that the till may have been slightly reworked during or since deposition by glacial meltwater or alluvial processes. Overburden deposits within the site area in the Brook A valley lowland consist of approximately 10 feet of grey fine sand, very likely of an alluvial or glaciofluvial origin. In the residential area north of the site and closer to the Exeter River, overburden thicknesses of up to 45 feet were identified in the vicinity of Brook A by seismic refraction data. It is likely that the thicker deposits in this area consist of glaciofluvial and/or glaciolacustrine deposits.

Bedrock outcrops were identified throughout upland areas in the study area including the Mottolo site just northwest of the piggery building. The bedrock in the study area is composed of metamorphic and igneous rock including grey, fine- to medium-grained biotite granofels; black, fine- to medium-grained biotite schist; and pink to grey, coarse grained granitic intrusions. The bedrock has been extensively deformed resulting in regional fault and joint orientations which are predominantly northeast-southwest and to a lesser extent, southeast-northwest. Based upon observations of rock cores and bedrock outcrops, bedrock is moderately fractured and slightly weathered. Measurements of fracture and joint orientations in study area bedrock outcrops indicated two dominant orientations, 45 degrees northeast and 120 degrees southeast. The northeast trend is consistent with the regional orientation of major fractures in southeastern New Hampshire. Indications of bedrock fracture zones or structural features in the study area were observed in the seismic data in the area of Brook A, and in one of the deep bedrock monitoring wells in the residential area which yielded much greater volumes of ground water than the other deep bedrock monitoring wells.

The Brook A drainage basin boundary defines the approximate location of the ground water divide for the overburden and upper bedrock aquifers in the study area. Ground water flow in the site area is primarily controlled by local topography, the slope of the bedrock surface, and Brook A. Ground water in the bedrock and overburden within the Brook A drainage basin flows to the east on the west side of Brook A, and to the west on the east side of the brook. Within the site area, Brook A and the drainage swale are locations of local ground water discharge. Detailed site area data indicate the ground water in the former disposal area flows both east in the overburden along the approximate path of the drainage swale, as well as downward into the upper bedrock and east to Brook A. Vertical hydraulic gradients in the upland area, including the former disposal area, are downward from the overburden to the bedrock; hydraulic gradients in the Brook A valley lowland area are upward from the bedrock to the overburden and Brook A. Beneath Brook A, the vertical hydraulic gradients indicate that ground water flows upward and discharges to the brook in a nearly vertical orientation. A

local ground water divide is present in the area of the piggery building and the on-site bedrock outcrop area. In the southern boundary area, both overburden and bedrock ground water appear to flow south before discharging to the headwater area for Brook A located to the south of the site.

Based upon ground water gradient and hydraulic conductivity measurements estimated from data collected during the RI, average ground water travel times from the former disposal area to Brook A through overburden range from one to four years. The estimated travel time for ground water to flow from the bedrock beneath the former disposal area to the overburden-bedrock interface beneath Brook A is approximately 1 to 14 days.

## 7.3 NATURE AND EXTENT OF CONTAMINATION

Analytical data collected during the RI indicate VOCs are the most prevalent contaminants identified at the Mottolo site related to past disposal and removal activities. Two contaminant source areas were identified: an approximately 150-by 75-foot area of soils in the former disposal area and a limited area of soils in the vicinity of the large concrete foundation pad west of the piggery building where drums were staged during EPA drum removal activities. The source of contaminants identified in the former disposal area was likely leaks and spills of liquids from the drums and pails disposed of in this area. The source of contamination in the southern boundary area was likely related to previous waste disposal activities or spillage or leaks from drums staged in this area during EPA removal operations.

The most common VOCs detected in soils in the former disposal area included the aromatic hydrocarbons toluene, xylenes and ethylbenzene; the chlorinated aliphatic hydrocarbons trichloroethene, methylene chloride and tetrachloroethene; the ketone acetone; and tetrahydrofuran. The highest concentrations of VOCs reported by soil screening data were located at or above the water table. The greatest total VOC concentration reported in a soil sample from this area was

465 parts per million (ppm). The volume of contaminated soil in the former disposal area is estimated to be in the range of 1,400 to 1,900 cubic yards. The source of contamination in the southern boundary area was not quantified, due to the likely limited extent of soil contamination.

VOCs were found to be the most significant contaminants detected in ground water, although arsenic was also detected in some wells at levels above the current arsenic drinking water standard. The VOCs most commonly reported at elevated concentrations include the aromatic compounds toluene, ethylbenzene, and xylenes; the chlorinated aliphatic hydrocarbons vinyl chloride, 1,1-dichloroethane, 1,2-dichloroethene, trichloroethene, and 1,1,1-trichloroethane; and tetrahydrofuran. Significant overburden ground water contamination extends from the former disposal area north to the drainage swale and east along a relatively narrow zone to Brook A. The distribution of VOCs in bedrock is similar to the distribution in overburden except that VOCs are generally reported at lower concentrations in ground water. However, due to a component of bedrock ground water flow to the northeast, higher relative levels of chlorinated VOCs and tetrahydrofuran were detected in a shallow bedrock well installed in the lowland area west of Brook A, approximately 300 feet north of the drainage swale confluence with the brook, as compared to the levels observed in an adjacent overburden well. Only low concentrations of VOCs were detected in ground water collected from one of four site area monitoring wells on the east side of Brook A in either the overburden or bedrock. This supports the finding that Brook A is a ground water discharge zone. Elevated concentrations of arsenic were detected in some overburden and bedrock monitoring wells also found to contain the highest reported VOC levels.

A limited number of chlorinated VOCs and tetrahydrofuran were also reported in one overburden well and two bedrock wells in the southern boundary area. The extent of overburden ground water contamination from this source area is expected to be limited to a relatively small area. Ground water contamination migrating in bedrock from this area is expected to migrate south and then east-southeast to the Brook A headwater area.

Analytical data collected as part of the RI off-site ground water quality monitoring program from three overburden monitoring wells, one shallow bedrock monitoring well, seven deep bedrock monitoring wells and twenty-two residential wells, indicated that trace concentrations of VOCs were detected at three bedrock monitoring well locations in three of the 24 samples collected and at three of the residential well locations in three of the 59 samples collected. The source(s) of the VOCs reported does not appear related to former disposal activities at the Mottolo site. The random nature of the contaminant distribution and the detection of contaminants in only one of several samples collected from each well location during the 1989 monitoring program support this conclusion.

Low levels of VOCs were reported present in sediment and surface water samples collected in the vicinity of the drainage swale confluence with Brook A. The sampling locations where these detected concentrations of VOCs were reported are coincident with the zone along Brook A identified to be receiving ground water containing the highest concentrations of VOCs. VOCs were not detected in either surface water or sediment samples collected approximately 400 feet downstream of the drainage swale confluence with Brook A, with the exception of a trace concentration of 1,1-dichloroethane in one surface water sample.

These data indicate that the extent of soil, ground water, surface water and sediment contamination emanating from the former disposal area is limited to a small area extending approximately from the former disposal area east and northeast to Brook A, the local ground water discharge feature.

## 7.4    CONTAMINANT FATE AND TRANSPORT

The source area most responsible for contaminants detected in ground water are contaminated soils in the former disposal area. Ground water quality data collected during the 1989 RI monitoring program indicate that the greatest release of contaminants to ground water likely occurs in the spring when water levels in the overburden rise as much as 5 feet into more highly contaminated soils.

Principal pathways for contaminant migration from this source area include lateral easterly ground water flow through the overburden to Brook A and the drainage swale, and easterly/northeasterly ground water flow through bedrock to Brook A. Since the bedrock has essentially no primary porosity, migration pathways and direction in the bedrock are influenced by the dominant 45-degree northeast and 120-degree southeast fracture and joint orientations. Contaminant distributions indicate the primary migration direction is east towards Brook A with a lesser northeast component of contaminant migration to Brook A along fractures and joints oriented in this direction.

The major component of contaminant migration in the southern boundary area are likely from the shallow overburden downward into bedrock ground water. Contaminants in bedrock ground water will likely migrate south and then southeast where they are expected to discharge with ground water at the Brook A headwater area. Due to the low concentrations of VOCs reported present in one overburden well in this area, contaminant migration in overburden ground water appears limited to a small area.

Based upon site conditions and analytical data collected during the 1989 monitoring program, contaminant transport can be described as being dominated by desorption, advection and dispersion processes. In general, the extent of ground water contamination appears to be governed by advective transport along ground water flow paths. As a result, the southern and eastern boundaries of the contaminated ground water plume originating from the former disposal area appear to be governed by ground water flow pathways. Dispersion is responsible for spreading of the VOC plumes to the north in Brook A valley in both overburden and bedrock ground water. Data indicate that VOCs in ground water migrate to Brook A where the VOCs will volatilize over a short distance downstream of their discharge point.

Contaminants migrating in ground water from the southern boundary area are expected to discharge to the Brook A headwaters. However, due to the relatively

lower level of VOCs observed in this area and lateral dispersion of these VOCs during transport, detectable levels of VOCs are not expected to be present in the Brook A headwaters surface water.

An analysis of historic ground water quality data collected between 1980 and 1989 showed significant declines in VOC concentrations during this period. These data indicate that the sources of contamination at the Mottolo site have been decaying over the last ten years, and that, even in the absence of site remedial activities, impacts associated with past waste disposal activities at the site will continue to decline in the future.

## 7.5   BASELINE RISK ASSESSMENT

The Mottolo Baseline Risk Assessment resulted in the selection of nine indicator compounds for site environmental media. Selected indicator compounds for ground water included arsenic, 1,1-dichloroethane, 1,2-dichloroethene (total), ethylbenzene, tetrahydrofuran, 1,1,1-trichloroethane, toluene, trichloroethene and vinyl chloride. Selected indicator compounds for site surface water were 1,1-dichloroethane and 1,2-dichloroethene (total), and for site sediment were 1,1-dichloroethane and 1,1,1-trichloroethane. Selected indicator compounds for site soils were ethylbenzene, toluene, and total xylenes. Among these indicator compounds, only arsenic, 1,1-dichloroethane, trichloroethene and vinyl chloride have been designated as carcinogens by EPA.

Potential exposure pathways were selected and evaluated based on calculated exposure doses for average maximum plausible and maximum calculated exposure scenarios. Current and future exposure scenarios were considered for areas on the Mottolo property and for off-site locations.

The risk evaluation and associated risk estimates calculated for the various exposure pathways suggested that risks to human health and the environment were within acceptable levels for most of the exposure pathways evaluated. Both

current and future land-use scenario exposure pathways with acceptable risks included dermal contact with and incidental ingestion of site surface water, dermal contact with and incidental ingestion of site sediment, and dermal contact with and incidental ingestion of site soil. The risk values derived for these pathways were based upon conservative assumptions of exposure frequency, exposure duration, and exposure dose.

Current risk from ingestion of contaminated ground water was not evaluated as there are presently no exposure pathways. Future risk estimates for potential ingestion of ground water derived from drinking water wells installed in bedrock at some future date within portions of the Mottolo property designated as Area 1, the former disposal area, and Area 2, the southern boundary area, were found to be outside the EPA acceptable levels of risk. Current or future risks via dermal contact with ground water derived from either Area 1 or Area 2 were calculated to have acceptable levels of risk. Future risks were also outside the EPA acceptable levels of risk for ingestion of ground water derived from overburden within Area 1; however, the installation and use of domestic wells installed in Area 1 overburden on the Mottolo site is not considered feasible.

Upon examination of potential risks for ingestion of ground water, it was found that incremental lifetime cancer risks were driven primarily by the reported presence of arsenic and vinyl chloride for ground water derived from the former disposal area, and by the presence of trichloroethene for ground water derived from within the southern boundary area. These estimates were based upon a conservative assumption that ingestion of ground water would occur on a daily basis over a 70-year lifetime. Non-carcinogenic risk from indicator compounds in ground water derived from bedrock appeared to be just above a hazard index of one for both areas, primarily the result of applying a provisional and conservative oral reference dose (RfD) to tetrahydrofuran.

Potential risks due to ingestion of arsenic in ground water were considered further in light of the debate surrounding the establishment of an acceptable drinking

water standard for arsenic. The compound is classified as a carcinogen, yet may also have a role as an essential nutrient. Moreover, naturally occurring background levels of arsenic may also fall outside the acceptable risk range of 1E-04 to 1E-06. On this basis, it was concluded that, due to the extremely conservative estimated risk values for arsenic, future potential risks through this exposure pathway would be more attributable to the presence of vinyl chloride than arsenic.

The potential risks from inhalation of vapors emanating from ground water during household use were evaluated qualitatively, and for some constituents were considered to carry risks similar in magnitude to ground water ingestion scenarios. However, the contribution of arsenic and tetrahydrofuran to the overall exposure dose was likely to be low.

With respect to potential environmental impacts posed by former waste disposal activities undertaken at the Mottolo site, neither current nor future adverse impacts were identified. The most likely adverse future impact to the environment would be impacts associated with land development to wetlands present on the Mottolo site.

## 7.6   DATA LIMITATIONS

In general, data collected during the RI were found to be adequate to support the objectives of the FS which are to develop and evaluate remedial alternatives that will protect human health and the environment. An additional data need identified during the RI concerned the long term effects of residually contaminated soil on on-site ground water quality. The southern extent of ground water contamination beyond the southern Mottolo property boundary was also identified as a potential data need. In response to the first data need, Balsam proposed, as part of the FS, to conduct a soil leaching study using on site soils collected from locations downgradient of the drum disposal area. An objective of this study was to assess the VOC leaching properties of residually contaminated saturated soils

immediately downgradient of the former disposal area assuming source removal had occurred. A secondary objective was to develop data for use in establishing soil target cleanup levels. The leaching study was conducted in June and July 1990 and the results of the study are to be included with the Mottolo site FS. Additional ground water quality data needs beyond the southern property boundary will be evaluated further during remedial design activities.

## 7.7  REMEDIAL ACTION OBJECTIVES

Based upon the data generated by the RI and the results of the baseline risk assessment, the reduction of potential future risks associated with the use of on-site bedrock ground water for domestic use was identified as the primary remedial action objective. Potential risks associated with other exposure pathways were found to be either within acceptable levels or, as in the case of overburden ground water, are likely to be reduced to within acceptable levels as a result of meeting the primary remedial objective. The risks associated with ingestion of bedrock ground water are driven primarily by the reported presence of arsenic, vinyl chloride and TCE. In order to reduce potential future risks associated with on site ground water use to within acceptable levels, source control and/or management of migration remedial actions are considered in the FS. Further reduction of risk associated with other exposure pathways will also result from achievement of the remedial action objective identified above.

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